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Long-Term Effects of Land Application of Domestic Wastewater, Roswell, New Mexico Slow Rate Irrigation Site

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Long-Term Effects of Land Application of Domestic Wastewater

Roswell, New Mexico, Slow Rate Irrigation Site

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This report presents the findings of a study on the long-term effects of applying treated domestic wastewater to farmland at Roswell, New Mexico. On the test site, a slow rate irrigation method was used for 33 years. Water, soil, and crop samples from this test site were compared with similar samples from nearby control sites irrigated with well water. Samples were also taken to detect viruses and coliform bacteria.

Alkalinity and nitrate were the only parameters found to be significantly greater at the test site. Only one parameter, phosphorus, was significantly greater in the effluent, the upper soil profile, and the plant leaves of the test site compared to the control site.

Soil analyses from six depths at different seasons indicated a rapid renovation of the wastewater. No viruses were detected in wells or plant samples, and coliform bacteria occurred only sporadically in early sampling results, possibly as a result of contamination during collection and processing. The report concludes with a projection for 100 or more years of useful life for the site, without undesirable effects from heavy metals, viruses, or excess nitrates in the groundwater. In addition, the site benefits from the extra plant nutrients contained in the wastewater that are not present in the well water.

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LONG-TERM EFFECTS OF LAND APPLICATION OF DOMESTIC WASTEWATER

Roswell, New Mexico, Slow Rate Irrigation Site

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FOREWORD

The Environmental Protection Agency was established to coordinate the administration of major Federal programs designed to protect the quality of our environment.

An important part of the agency's effort involves the search for information about environmental problems, management techniques, and new technologies through which optimum use of the nation's land and water resources can be assured and the threat pollution poses to the welfare of the American people can be minimized.

EPA's Office of Research and Development conducts this search through a nationwide network of research facilities. As one of these facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs including the development and demonstration of soil and other natural systems for the treatment and management of municipal wastewaters.

Although land application of municipal wastewaters has been practiced for years, there has been a growing and widespread interest in this practice in recent years. The use of land application received major impetus with the passage of the 1972 amendments to the Federal Water Pollution Control Act. The 1977 amendments to the Act gave further encouragement to the use of land application and provided certain incentives for the funding of these systems through the construction grants program. With the widespread implementation of land application systems, there is an urgent need for answers to several major questions. One of these questions regards the long-term effects of land application on the soil, crops, groundwater, and other environmental components. This report is one in a series of ten which documents the effects of long-term wastewater application at selected irrigation and rapid infiltration study sites. These case studies should provide new insight into the long-term effects of land application of municipal wastewaters.

This report contributes to the knowledge which is essential for the EPA to meet the requirements of environmental laws and enforce pollution control standards which are reasonable, cost effective, and provide adequate protection for the American public.

William C Galegar

William C. Galegar
Director
Robert S. Kerr Environmental Research Laboratory

ABSTRACT

This report presents the findings of a study on the long-term effects of applying treated domestic wastewater to farmland at Roswell, New Mexico. On the test site, a slow rate irrigation method was used for 33 years. Water, soil, and crop samples from this test site were compared with similar samples from nearby control sites irrigated with well water. Samples were also taken to detect viruses and coliform bacteria.

Data on a number of parameters were evaluated against information about the natural features of the Roswell physiographic region. Methods used in the field and laboratory analyses are described in sufficient detail to provide a basis for comparison of these results to other studies.

An essential aspect of evaluating water analyses is understanding the hydrogeology of the area. Knowledge of depth and movement of groundwater and location and thickness of aquifers was essential in interpreting data from wells strategically placed on both test and control sites.

Differences in eight mean concentrations out of thirty-nine parameters analyzed statistically were found to be significant for the effluent at the test site as compared to the irrigation water at the control site. Seven of the eight parameters were greater for the effluent at the test site, and one was greater for the irrigation water at the control site. For the comparison of the groundwaters, seven parameters were found to be significantly different. Alkalinity and nitrate were the only parameters found to be significantly greater at the test site. Only one parameter, phosphorus, was significantly greater in the effluent, the upper soil profile, and the plant leaves of the test site compared to the control site.

Soil analyses from six depths at different seasons indicated a rapid renovation of the wastewater. In most cases, the upper layers of the soil (0-30 cm) adequately trapped chemicals, such as ammonium nitrogen and phosphorus, which had higher concentrations in wastewater than well water.

No viruses were detected in wells or plant samples, and coliform bacteria occurred only sporadically in early sampling results, possibly as a result of contamination during collection and processing. The report concludes with a projection for 100 or more years of useful life for the site, without undesirable effects from heavy metals, viruses, or excess nitrates in the groundwater. In addition, the site benefits from the extra plant nutrients contained in the wastewater that are not present in the well water.

This report was submitted in partial fulfillment of Contract No. 68-

02-2363 by Benham-Blair & Affiliates, Inc., as the principal contractor; Engineering Enterprises, Inc., as subcontractor; with three cooperating companies: Sheaffer and Roland, Inc.; D.E. Matschke Company; and W.J. Bauer Consulting Engineers, Inc.; under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period from January, 1976, to November, 1977; work was completed as of June, 1978.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

acre-ft -- acre-foot
BOD -- biochemical oxygen demand
BOD_5 -- 5-day biochemical oxygen demand
cm -- centimeters
cm/hr -- centimeters per hour
COD -- chemical oxygen demand
DO -- dissolved oxygen
exch -- exchangeable
extr -- extractable
fecal coli -- fecal coliform
g -- grams
gal -- gallons
GL -- ground level
gpd -- gallons per day
gpd/ft -- gallons per day per foot
gpm -- gallons per minute
ha -- hectares
hr -- hours
in -- inches
in/hr -- inches per hour
kg -- kilograms
kg/ha -- kilograms per hectare
kg/ha/yr -- kilograms per hectare per year
km -- kilometers
L -- liters
L/s -- liters per second
L/d/m -- liters per day per meter
lb -- pounds
lb/acre -- pounds per acre
lb/acre/hr -- pounds per acre per hour
m -- meters
m^3 -- cubic meters
MCL -- maximum contaminant level
mg/g -- milligrams per gram
mg/L -- milligrams per liter
Mgal/d -- million gallons per day
Mgal/d/ft -- million gallons per day per foot
mi -- miles
mL -- milliliters
mm -- millimeters
mo -- month

ng/g -- nanograms per gram
ng/L -- nanograms per liter
nm -- nanometer
sq ft -- square feet
SR -- slow rate irrigation
SS -- suspended solids
SWL -- static water level
TDS -- total dissolved solids
TOC -- top of casing
total coli -- total coliform
yr -- year
μg/g -- micrograms per gram
μg/L -- micrograms per liter
μmhos/cm -- micromhos per centimeter
#/100 mL -- number of coliform per 100 milliliters of sample

SYMBOLS

Al -- aluminum
As -- arsenic
B -- boron
Ca -- calcium
Cd -- cadmium
Cl -- chlorine
Co -- cobalt
Cr -- chromium
Cu -- copper
Fe -- iron
Hg -- mercury
H_2SO_4 -- sulfuric acid
K -- potassium
Mg -- magnesium
Mn -- manganese
N -- nitrogen
Na -- sodium
NH_3 -- ammonia
NH_4 -- ammonium
Ni -- nickel
NO_2 -- nitrite
NO_3 -- nitrate
P -- phosphorus
Pb -- lead
S -- sulfur
Se -- selenium
SO_4 -- sulfate
Zn -- zinc
$>$ -- greater than
$<$ -- less than
μ -- micron

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Each of the participating companies had a primary leader or coordinator who took major responsibility for bringing the project to completion. They were Ernest L. Koerner for Benham-Blair and Affiliates, Inc.; D. Alan Haws for Engineering Enterprises, Inc.; Raymond H. Brand for Sheaffer and Roland, Inc.; and Donald E. Matschke for D.E. Matschke Company. Messrs. William J. Bauer, Keith E. Bennett, R. LeRoy Carpenter, Paul K. Law, Geoffrey W. Leeper, Dennis G. Lund, Lelan K. Martin, Harold E. Namminga, W. Russell Street, Herbert M. Schornick, and John R. Sheaffer also made substantial contributions to the project.

In addition, the cooperation of the landowners and personnel from the City of Roswell and the New Mexico Environmental Improvement Agency was appreciated.

SECTION 1

INTRODUCTION

Land application of domestic wastewater is not a new concept although it has only been in recent years that land treatment has received renewed attention. This attention has been focused in two general areas: 1) economical wastewater renovation including increasing crop yields on agricultural soils; and 2) potential soil and groundwater pollution including potential health hazards. Decisions regarding wastewater management must consider these areas.

Proper design, operation, and monitoring of land application systems require data concerning the long-term effects of applying wastewater on land under a variety of operating conditions. There is a need for these data from areas where wastewater has been applied for at least 10 years.

For 33 years treated domestic wastewater from Roswell, New Mexico, has been used for irrigation. The particular application method used is slow rate irrigation (SR) in which effluent flowing through a concrete-lined ditch is channeled to run down furrows in the fields (Figure 1).

In this research study conducted over a one-year period, test and control plots were selected for comparison of certain parameters. Samples were collected of the sewage effluent, groundwater, surface water runoff, soils, and plants grown on the test plots. Field laboratory analyses of some samples at the site and later, complete chemical laboratory analyses provided the data presented in this report.

The objective of the study was to investigate the long-term effects of applying wastewater effluent to the land. Possible health hazards of heavy metal accumulation in plants; potential contamination of groundwater supplies with bacteria, viruses, or excessive nitrates; and undesirable changes in the chemistry of the soil for maintaining high crop yields were key issues to be addressed in the study. The scope of the study consisted of one year of field investigation and focused attention on heavy metals, pathogens, nitrogen, and phosphorus.

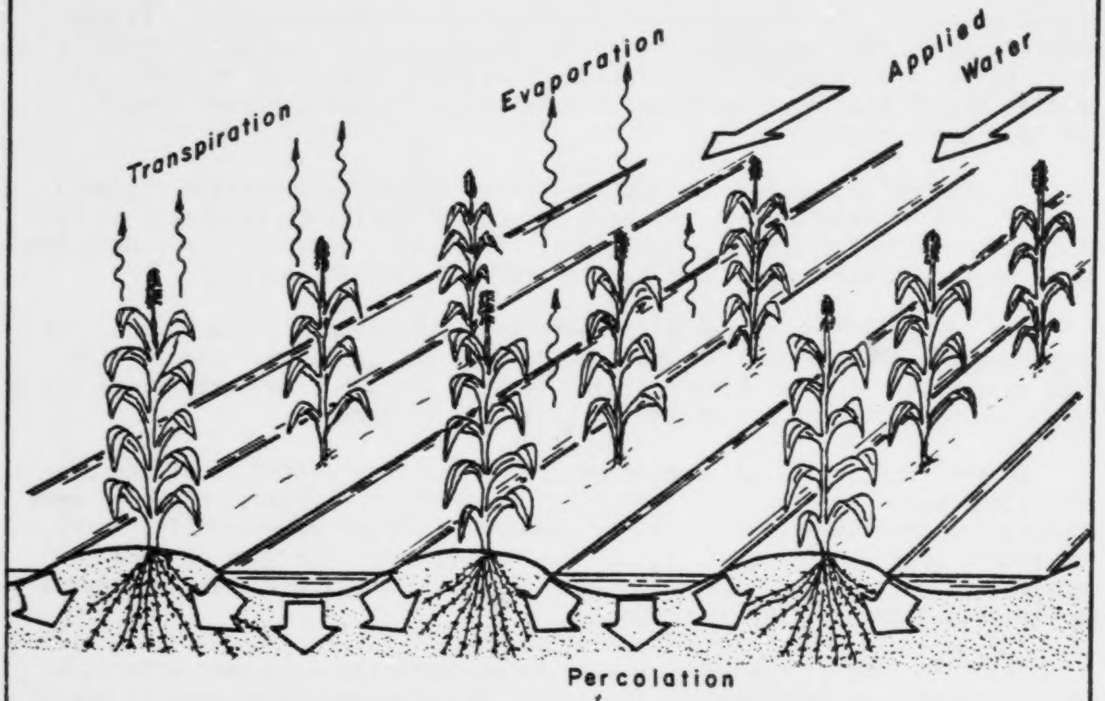


Figure 1. Ridge and furrow flood irrigation.

SECTION 2

CONCLUSIONS

An analysis of the waters, soils, and plants at the Roswell site has indicated that the use of wastewater for irrigation resulted in several long-term beneficial effects. The specific major findings showed that:

1. Indicator viruses or total and fecal coliform bacteria have not penetrated the soils and reached the underlying groundwater as a result of 33 years of irrigation with effluent from the Roswell, New Mexico, wastewater treatment plant. No viruses were detected in the groundwater.

2. No trace of indicator viruses was found either on the surface or inside the tissue of the leaf and grain portions of the corn grown on the effluent-irrigated land.

3. Metals such as zinc, copper, and chromium that were measured in small concentration in the irrigation effluent were removed and sufficiently immobilized by the soil and, after 33 years, are not being assimilated by crops at any greater rate than for comparable crops at groundwater-irrigated locations with comparable soils.

4. More toxic metals such as cadmium, lead, and mercury have been demonstrably absent in the irrigation effluent, the underlying groundwater, and the irrigated corn crop.

5. Arsenic and selenium concentrations in the effluent-irrigated soil were low and comparable to concentrations in soils that have not received effluent irrigation.

6. Extractable metals in the effluent-irrigated soil, such as boron, were adequate for crop nutrition, below toxic levels, and comparable with extractable concentrations in groundwater-irrigated soils.

7. The plant nutrients nitrogen and phosphorus have increased in the effluent-irrigated soil by approximately 50 percent as contrasted with groundwater-irrigated soils.

8. No harmful concentrations of the herbicides and pesticides endrin, lindane, methoxychlor, toxaphene, 2,4-D, and 2,4,5 TP silvex were present in the irrigation effluent or groundwater. Lindane was

present at measurably higher concentrations in the groundwater at the effluent-irrigated site as contrasted with the groundwater-irrigated site but at concentrations well below the current National Interim Primary Drinking Water Regulation maximum contaminant level.

9. Nitrate nitrogen at an average concentration in the range of 5 to 7 mg/L and 3 to 4 percent of the applied nitrogen is exiting in the effluent-irrigated site by way of the underlying groundwater.

10. Nitrogen loss to volatilization and denitrification is projected to be in the range of 3 to 30 percent at the effluent-irrigated site.

11. Phosphorus uptake by the effluent-irrigated soils has penetrated to the upper 30 cm (12 in) of the soil profile after 33 years of effluent application and phosphorus removal to an average 0.04 mg/L soluble phosphorus. The projected life for continued phosphorus removal for the irrigation effluent on these soils is in excess of 100 additional years.

12. All parameters observed for the groundwater, soils, and plants support the continued use and longevity for the 33-year effluent-irrigated site for continued effluent irrigation, crop benefits, and wastewater reclamation.

SECTION 3

SITE-SELECTION PROCESS

GENERAL CRITERIA

Earlier Approaches

An earlier report (Bauer, 1976) defined a number of working approaches for the site-selection process. These were initially used to provide direction in the data-gathering phases. The earlier approaches included the following:

Soil Chemistry--

The chemical reaction of the soil with the chemicals in the applied wastewater takes place first in the upper layers of the soil. After these upper or plow layers have become saturated, reactions take place at progressively lower elevations. The distribution of accumulated chemicals resulting from the application of wastewater is studied from the point of view of this simple model of the process.

Biological--

Some of the materials applied to the land in the wastewater are removed in the form of crops. To calculate an overall materials balance, an estimate of the total quantity of materials removed by crops must be made.

Hydrological--

Water moves through the earth in two major forms: (1) as soil water through the unsaturated zone, where the two fluid properties of fluid weight and surface tension dominate the movements, and (2) as groundwater through the saturated zone, where the two fluid properties of fluid weight and viscosity dominate the movements. Both of these movements are subject to the laws of fluid mechanics, permitting mathematical models to be set up for a particular site. Such models are useful in guiding the exploratory and sampling programs and in interpreting the results of such programs. The models enable one to define a "plume" of water that originates in the wastewater application site. This plume is the only part of the soil and groundwater that is affected by the application of the wastewater. All other water outside this plume remains unaffected. This is an extremely important concept in guiding the program of sampling and in interpreting the results.

Applications to Sites

The foregoing approaches aid in defining parameters that help to distinguish one site from another. Several of these parameters are as follows:

Uniform Permeability of Soil--

Each test site and control site should have the same type of soil with the same general, reasonably uniform permeability. The soil should not contain any well-defined channels through which the applied water could escape contact with the chemicals in the soil mass.

Same Site--

The same site should have been used for a long time. If wastewater had been applied to first one and then another site over the period of operation, the concept of the long-term effect would not be applicable.

Depth to Groundwater--

The depth to the groundwater should be sufficient to permit good crop production, yet shallow enough to allow economical sampling of the water. The thickness of the aquifer should be adequate to permit a large body of soil to react with the applied wastewater.

Accounting for Chemical Elements--

Sufficient data should be available to estimate the total mass of chemical elements applied with the wastewater, the amount percolated through the soil, the amount taken off in the crops, and the amount that has remained in the soil.

Constant Quality--

No substantial change should have occurred in the chemical quality of the applied wastewater over the period being studied.

Extraneous Sources--

If chemicals other than those in the wastewater have been applied on or near the study sites, such an application can introduce uncertainties into the operation that would make the analyses difficult. Other factors being equal, sites at which other sources of chemicals have been applied should be avoided.

General Criteria Supplied by EPA

The EPA also specified certain other general criteria for the selection of sites. These criteria are as follows:

1. Flow rates should be at least 4.38 L/s (0.1 Mgal/d).

2. Historical records should be available for at least 10 years.

3. The applied wastewater should be effluent from either primary or secondary treatment.

4. A good control site should be within a reasonable distance and have the same general type of soil and hydrogeological conditions.

NEW MEXICO SITES

Preliminary Evaluations

Sixteen sites which practiced some degree of irrigation with wastewater were listed initially, using the STORET data supplied by the EPA. Table 1 lists the 16 New Mexico sites. By a process of evaluation that relied upon written and telephone information, the list of 16 was reduced to 3 sites, each of which was visited. Reasons for elimination are given in Table 1.

Site Visits

Three sites were visited: Roswell, Tularosa, and Alamogordo. As indicated in Table 1, only Roswell satisfactorily met the criteria that had been established. The records at the other two sites were too incomplete to calculate the total quantity of wastewater that had been applied. No further consideration was given to the Tularosa or Alamogordo sites.

The process of site selection for the study of the use of wastewater to irrigate crops in New Mexico was remarkably direct. The Roswell site was unmistakably the proper choice, having none of the drawbacks of the other potential sites.

The process of selection deliberately avoided golf-course irrigation sites. It was felt that more significant information could be obtained from the study of cropland irrigation.

TABLE 1. COMPARISON OF SITES LOCATED IN NEW MEXICO[a]

Location	Uniform Permeability	Same Site	Groundwater Depth	Aquifer Thickness	Mass Balance	Wastewater Quality	Extraneous Sources	Total
Roswell[b]	+1*	+1	+1	+1	+1	+1	+1	7
Tularosa[c]	+1	+1	+1	+1	-1	0	-1	2
Alamogordo	+1	+1	+1	+1	-1	0	0	3

* +1 = Parameter Favorable; -1 = Parameter Unfavorable; 0 = Neutral

Notes:

a. Thirteen sites investigated were rejected for the following reasons:

A. Only golf course irrigation practiced: Gallup, Santa Fe, Los Alamos, Silver City.
B. Incomplete records, mixed water, or similar doubt about input: Eunice, Dexter.
C. Unknown operation - Some contamination already: Hobbs, Jal, Levington, Clovis, Deming.
D. Extraneous source - Leaking lagoon next to irrigation site: Portales.
E. Too small and too new: Clayton.

b. Roswell is obviously the first choice of the New Mexico sites, as the wastewater applied to the study site is not mixed with other sources of water. One can therefore evaluate the total quantity of applied chemicals with relative precision. All of the other conditions were also good at Roswell.

c. The figures listed for the soil and groundwater conditions at Tularosa and Alamogordo were arbitrarily assigned at +1 to give them the benefit of the doubt, as the flow and water quality records were so incomplete as to eliminate these two sites from further consideration. The soil conditions were not investigated to the same extent as were those at Roswell.

SECTION 4

DESCRIPTION OF SITE

GENERAL

Roswell is located at map coordinates latitude 33^{o} 18'N longitude 104^{o} 32'W in Chaves County in southeastern New Mexico (Figure 2). The city had a population of 43,000 in 1975 and has two facilities of higher learning, the New Mexico Military Institute and Eastern New Mexico University (ENMU). Until 1974, an air base located approximately 13 km (8 mi) south of Roswell provided a major source of income for the city. This air base was abandoned in 1975. The economic base is presently farming, feedlots, tourism, and light industry. The only major industry is the Glover packing plant.

TOPOGRAPHY

Except for small areas in the extreme southwestern part and on the High Plains along the eastern boundary of the county, essentially all surface runoff from this county enters the Pecos River drainage system. The Pecos River flows generally in a north-to-south direction through the central part of the county. Numerous tributary streams enter the Pecos River from the west and a few relatively small ones from the east. The larger and more extensive drainage and arroyos on the west, which originate in the Capitan, Sierra Blanca, and Sacramento mountains to the west, include Salt Creek, Arroyo Del Macho, Berrendo Creek, Rio Hondo, Rio Felix, and the upper part of the Rio Penasco. Although a few of these large streams are perennial in their upper reaches, they are generally intermittent in the county or flow only following periods of heavy rainfall. The streams entering the Pecos River from the east drain relatively small areas and are all intermittent.

A number of different and varied types of topography occur within the county. In the part of the county extending from just north of Roswell to the south county boundary, a broad, nearly level to gently sloping alluvial plain and terrace area extends eastward from the western uplands to the Pecos River. This plains area is commonly interspersed with undulating to gently rolling ridges and uplands in the western part, where it joins the limestone uplands.

Nearly level to very gently sloping floodplains border many of the principal drainages. These occur mainly in the valley bottoms of Salt Creek, Berrendo Creek, Rio Hondo, Rio Felix, Arroyo Del Macho, and the Pecos River as well as in valleys adjacent to a number of other small intermittent drainages. The elevation at Roswell is about 1,097 m (3,600 ft) (New Mexico State University, 1971).

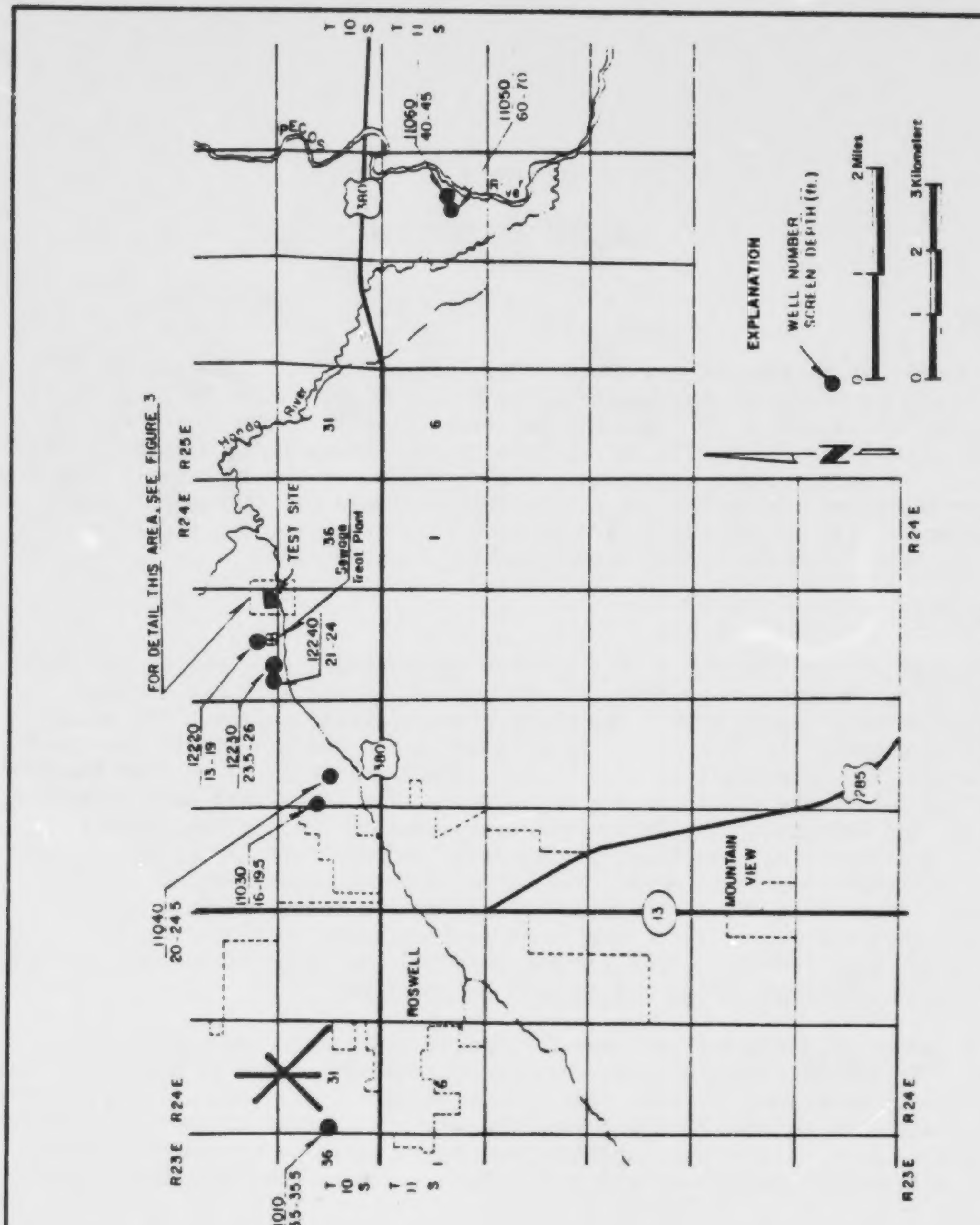


Figure 2. General location map.

TEST SITE

The test site consists of about 6.5 ha (16 acres) and is located about 0.6 km (3/8 mi) east of the sewage treatment plant. Wastewater-irrigated farmland is located on three sides, with the Rio Hondo on the southern side. The 8.1 ha (20 acres) between the test site and the sewage treatment plant has been irrigated with wastewater for more than 30 years, and sludge has been applied for the last 2 or 3 years. The land to the north and east of the test site has been irrigated with mixed wastewater and groundwater. About 9.3 ha (23 acres) of adjacent land to the north and east drains onto the test site.

The test site slopes gently toward the Rio Hondo and is flood-irrigated (ridge and furrow) from a concrete-lined ditch located on the northern edge of the site.

CONTROL SITES

Two control sites (A and B) were selected for the Roswell study (Figure 3). Site A is located about 2.4 km (1.5 mi) west of the test site and was used to test the groundwater quality upstream of the test site. This site is flood-irrigated with well water from the artesian aquifer. A sample of the irrigation water was collected on the first sampling trip. Monitoring well 11030 was screened in the water table aquifer and was sampled on all four sampling trips. The soils were different from those on the test site.

Control site B is located about 6.4 km (4 mi) east of the test site. The soils are the same as those on the test site. Corn was grown on both sites during the study period. This control site consists of more than 16 ha (40 acres) that are flood-irrigated with well water from the artesian aquifer. The irrigation water was sampled on the first and fourth sampling visits. Monitoring wells 11050 and 11060 were screened in the water table aquifer and were sampled on all four sampling trips. The crops and soils were sampled for comparison with those on the test site.

Summary of Test Site and Control Site B

The Roswell site was an especially appropriate setting for both test and control sites. A summary of characteristics of the two sites is given in Table 2.

The two sites were comparable, the only difference being the use of sewage effluent rather than well water for irrigation. Thus, an excellent comparison of the two sites can be made.

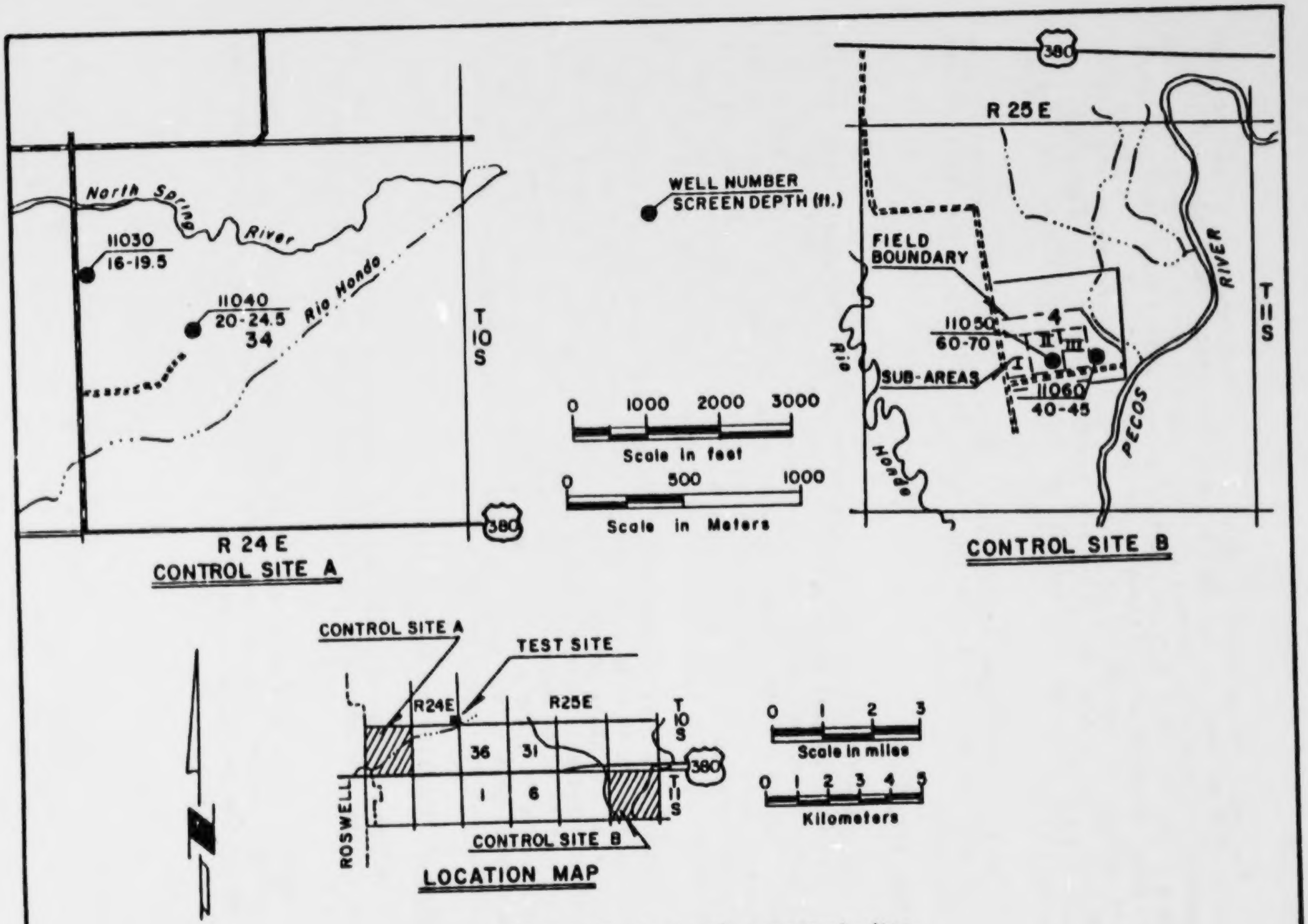


Figure 3. Irrigation control sites.

TABLE 2. SUMMARY OF TEST SITE AND CONTROL SITE B CHARACTERISTICS

Characteristic	Test Site	Control Site B
Size of site, ha	8.1	16.0
Method of irrigation	Ridge & furrow	Ridge & furrow
Depth of irrigation, m/yr.	0.8	0.8
Thickness of underlying aquifer, m	10-12	10-12
Depth to groundwater, m	2-4	2-4
Direction of groundwater flow	East	East
Type of soil (loam)	Balmorhea	Balmorhea
Source of water	Sewage effluent	Well water
Duration of irrigation	33 years	30 years

GROUNDWATER HYDROLOGY AND GEOLOGY

General

The Roswell groundwater basin in southeastern New Mexico is a unique and complex system of aquifers. Several studies dealing with the basin have been made. The most complete was in 1933 (Fiedler and Nye, 1933), and one of the most recent was published in 1968 (Kinney, 1968). Figure 4 is a generalized geologic map for the Roswell area.

Physiography and Drainage

The Roswell Basin is bounded by the Capitan, Sacramento, and Guadalupe mountains about 125 km (78 mi) west of Roswell, the Seven Rivers Hills about 96 km (60 mi) south of Roswell, and the east bank of the Pecos River to the east. The northern boundary of the basin is indefinite but probably is about 125 km (78 mi) north of Roswell.

The surface-water boundaries of the Roswell Basin coincide with its physiographic boundaries. The majority of the streams that flow across the Roswell Basin originate in the mountains to the west and flow eastward to the Pecos River.

Surface-water runoff from within this area contributes to the aquifer through influent seepage as the streams cross the basin. The area from which precipitation percolates directly to the aquifer does not extend as far to the west and is probably limited to about 77 km (48 mi) from Roswell.

The Artesian Aquifer

Although several aquifers are present, the principal formation of the

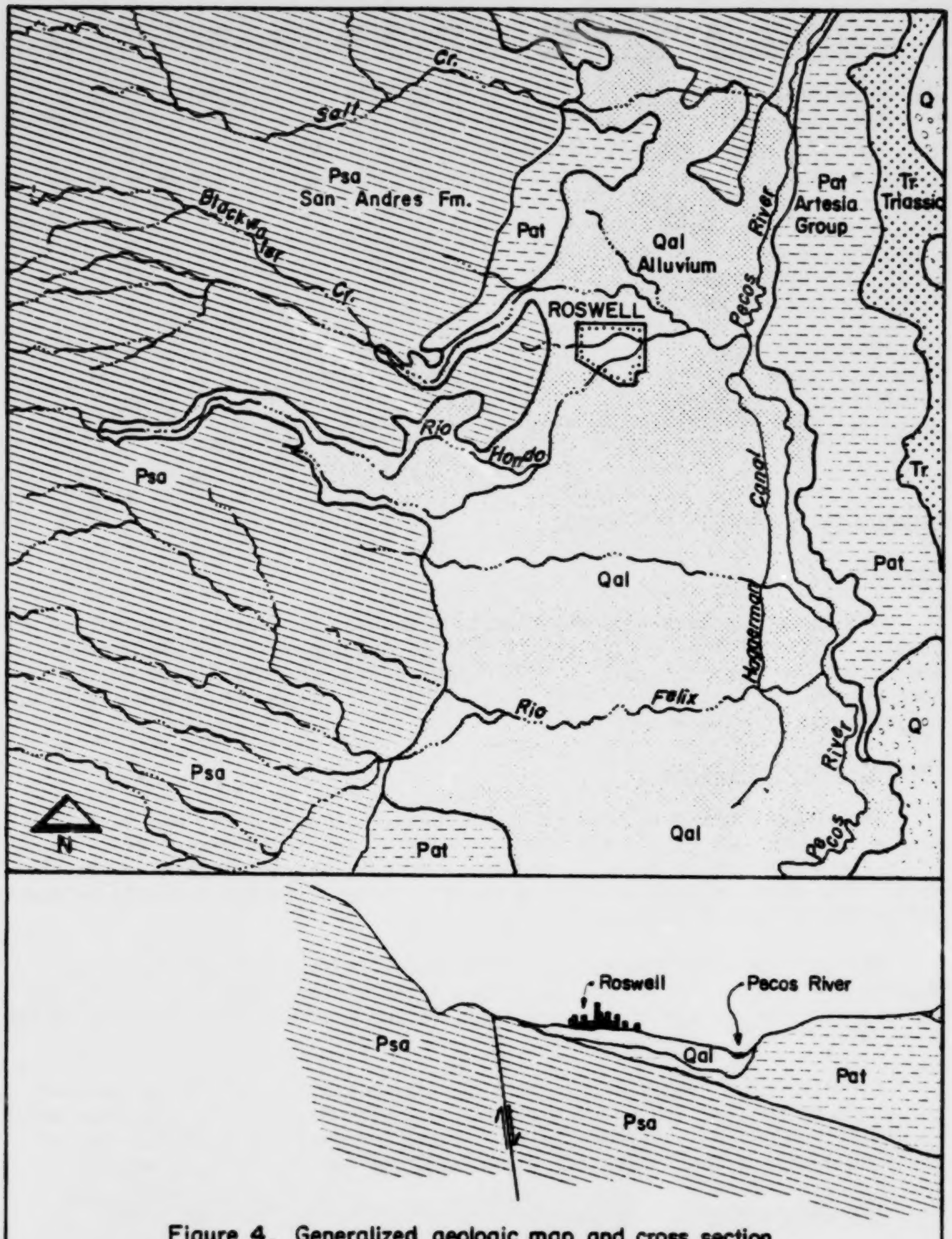


Figure 4. Generalized geologic map and cross section of Roswell, N.M. area.

artesian reservoir is the San Andres Limestone. Water occurs in an unconfined condition in the San Andres Limestone about 19 to 24 km (12 to 15 mi) west of Roswell (R.21E.) and becomes effectively confined (or artesian) by the overlying Grayburg and Queen Formations at the western edge of Roswell (R.23E.). An elongated confined aquifer from 19 to 32 km (12 to 20 mi) wide parallels the Pecos River for about 145 km (90 mi). Within a smaller area 11 to 19 km (7 to 12 mi) wide and 105 km (65 mi) long many early flowing wells were drilled. Development within the basin began prior to 1900. By 1905 there were approximately 485 artesian wells, and this had increased to 1,400 wells by 1927. These wells initially flowed from 12 to 380 L/s (200 to 6,000 gpm), but at most wells, the artesian flow had decreased considerably by 1927. Fiedler and Nye did note two 30.5 cm (12 in) wells drilled in 1926 and 1927 that initially flowed 380 and 360 L/s (6,000 and 5,700 gpm), respectively (Fiedler and Nye, 1933). These wells were located 11 km (7 mi) southeast and 9.6 km (6 mi) southwest of the test area.

Fiedler and Nye's 1926 listing included 10 wells in Section 26 (test area), 32 wells in Section 27, 63 wells in the remaining 7 adjoining sections, and 126 wells directly west in Sections 32 and 33. Initial flow of these wells ranged from 6 to 145 L/s (100 to 2,300 gpm) but more commonly was 32 to 63 L/s (500 to 1,000 gpm).

By 1926 most of the wells in Section 32 and the western half of Section 33 had ceased to flow and were either abandoned or used as domestic supply, while those to the east continued to flow at reduced rates of 20 to 45 L/s (300 to 700 gpm) and were used for irrigation.

Although it is interesting to note the magnitude of early development, it is pertinent to the study only as an illustration of the potential for leakage within the area from the artesian aquifer to the overlying shallow aquifer through abandoned wells.

Earlier studies (Fiedler and Nye, 1933, and Hantush, 1955) estimated that the natural upward leakage contributed significantly to the recharge of the shallow aquifer of 100,000,000 m^3/yr (80,200 acre-ft per year). However, the Roswell Geological Society publication discounted the natural upward leakage as being significant in most areas of the basin (Kinney, 1968). Regardless of natural leakage, the potential for man-made leakage within the test area is high.

The Shallow Aquifer

The San Andres Formation is overlain and confined by the Grayburg-Queen Formation. Although considered to be an aquitard, the formation is utilized as an aquifer near Roswell and is artesian in places. The Grayburg-Queen Formation is overlain by the Seven Rivers Formation, which consists of thin-bedded shales, siltstones, and sandstones.

The base of the shallow aquifer that underlies the test site extends downward to the approximate top of the Queen Formation and includes part of the Seven Rivers Formation to which it is hydraulically connected.

The shallow aquifer within the Roswell area consists of 61 m (200 ft) of valley fill that was deposited by the Pecos River as it migrated eastward. This fill consists of sands of the Queen Formation and Seven Rivers Formation intermixed with more recent sediments deposited by the Pecos River and the alluvium along the Pecos River and its tributaries. Fiedler and Nye named the resulting terraces in order of decreasing age from west to east: the Blackdown terrace, which developed on outcrops of the Queen Formation; the Orchard Park terrace, which developed in outcrops of the Seven Rivers Formation; and the Lakewood Terrace, consisting of sediments deposited by the Pecos River and its tributaries (Fiedler and Nye, 1933). These terraces are generally considered to be interconnected and are referred to as the shallow watertable aquifers.

Test Site

On the test site, however, the upper alluvium (Lakewood Terrace) is not as directly connected to the shallow aquifer as indicated above, and the shallow aquifer cannot be considered unconfined. This is evidenced by water-level fluctuations of 7.6 m (25 ft) in deep well 12070 during the irrigation season (Table 3). During this period the alluvium wells fluctuated less than 1 m (3 ft). Fiedler and Nye noted one well in the NE 1/4 of NE 1/4 Sec. 35, T. 10 S., R. 24 E., within 400 m (0.25 mi) of the test site that initially flowed at a rate of 43 L/s (680 gpm) and was only 30 m (98 ft) deep (Fiedler and Nye, 1933).

Stratigraphy--

The stratigraphy of the site is: alluvium to 10 m (35 ft), semi-confined valley fill (shallow aquifer) from 10 m (35 ft) to approximately 60 m (200 ft), then 15 to 45 m (50 to 150 ft) of Grayburg-Queen Formation with the San Andres Limestone occurring between 76 and 107 m (250 and 350 ft) below the surface. Fiedler and Nye (1933) indicate that the top of the San Andres occurs at about this depth, based on several well logs within the area, and that artesian water was sometimes encountered above what they classified as the San Andres Formation.

Aquifer Characteristics--

The coefficient of transmissibility of the San Andres Formation varies from 1,240,000 L/d/m (0.1 Mgal/d/ft) at the northern and southern limits to more than 23,600,000 L/d/m (1.9 Mgal/d/ft) in the Roswell area. Near the test area, the coefficient of transmissibility is estimated to be on the order of 12,400,000 L/d/m (1 Mgal/d/ft), and the piezometric surface on the artesian aquifer was about 1,075 m (3,527 ft) in 1968 or about 5.2 m (17 ft) above ground level.

The coefficient of transmissibility of the shallow aquifer within the test area is about 1,240,000 L/d/m (0.1 Mgal/d/ft), and water elevations fluctuated in response to the irrigation demands from 8 m (26 ft) below the surface during the summer to 0.1 m (0.4 ft) below the surface elevation of 1,069 m (3,507 ft) in January, 1977. Groundwater flow in the shallow aquifer is generally to the east towards the Pecos River with a piezometric gradient of 0.0021.

TABLE 3 WELL SUMMARY SHEET

WELL NUMBER	TOTAL DEPTH (Ft. below G.L.)	SCREEN DEPTH (Ft. below G.L.)	PUMPING RATE (G.P.M.)	TOP OF CASING (Ft. above G.L.)	ELEV. TOP OF CASING (m.s.l.)	ELEV. S.W.L. (m.s.l.) 20 JUNE 1976	S.W.L. (Ft. below T.O.C.) 20 JUNE 1976	S.W.L. (Ft. below T.O.C.) 19 OCT. 1976	S.W.L. (Ft. below T.O.C.) 5 JAN. 1977	S.W.L. (Ft. below T.O.C.) 25 APR 1977	REMARKS
Roswell Test Site Wells:											
12030	29	22-27	25	0.5	3508.2	3499.7	8.5	7.61	7.78	8.66	
12041*	32	11-13	0.2	0.6	3508.4	3500.4	8.0	7.5	7.79	8.37	
12042*	32	20-22	--	0.5	3508.3	3499.7	8.6	7.56	7.71	8.43	
12043*	32	27-29	15	0.4	3508.1	3499.7	8.4	7.4	7.56	8.57	
12050	23	12-17	2	0.6	3509.1	3499.7	9.4	7.57	7.5	9.08	
12060	14	6-11	--	0.6	3508.8	3500.9	7.9	7.05	7.05	8.11	
12070	115	100-105	--	0.9	3508.5	----	26.73	4.17	1.36	26.11	Artesian well
12080	31	19-29	--	0.3	3508.0	3499.7	8.3	--	7.6	8.1	Water Level Recorder Well
12090	23	16-18	5	0.5	3509.4	3501.6	7.8	6.92	7.0	7.9	
12100	33	23-33	--	0.6	3508.4	3499.7	8.7	8.3	9.1	8.72	
12110	30	21-31	--	0.3	3508.1	3499.7	8.4	8.11	8.8	8.45	
12120	28	18-28	--	0.5	3508.3	3499.7	8.6	8.26	9.05	8.61	
12130	13	9-10	6	1.5	3509.7	3500.1	9.6	9.3	10.25	10.02	
12140	20	18-20	5.5	0.4	3508.4	3498.8	8.6	8.4	7.65	8.89	
12150	10	7-10	5	0.7	3509.8	3501.4	8.4	8.15	8.25	8.33	
12160	21	18-21	2	0.4	3508.3	3500.4	7.9	6.88	6.8	7.82	
12170	10	7-9	--	0.7	3511.4	3502.1	9.3	8.72	9.95	dry	
12201*	35	10-12	20	0.6	3509.3	3500.3	9.0	7.05	7.55	9.5	
12202*	35	20-22	20	0.7	3509.4	3500.2	9.2	7.14	7.65	9.57	
12203*	35	30-33	9	0.8	3509.5	3500.5	9.0	7.3	7.9	9.7	
12210	12	9.5-11.5	7.5	0.5	3509.8	3501.7	8.1	7.35	7.5	8.15	
12220	28	13-19	2	0.5	3520.2	3509.0	11.2	14.84	15.89	15.16	
12230	28	23.5-26	37.5	1.1	3524.9	3513.9	11.0	---	10.41	11.28	
12240	28	21-24	--	1.9	3526.5	3512.5	14.0	13.26	12.78	13.86	
Roswell Control Site Wells:											
11010	35	25.5-35.5	--	0.80	3590.6	3563.7	26.9	--	--	--	
11030	21	16-19.5	3.5	1.1	3547.0	3537.0	10.0	11.12	10.99	10.84	10/21/76 Elevation change--0.21
11040	25	20-24.5	--	0.8	3547.2	3532.2	15.0	--	--	--	
11050	70	60-70	22	0.87	3463.3		--	10.07	8.45	12.7	
11060	45	40-45	3	1.04	3463.5		--	9.38	7.34	13.28	

*Three wells installed in one hole with bentonite seal between well screens.

Pumping tests conducted in the alluvium on the test site during the construction phase of the project indicated a coefficient of transmissibility of 248,000 L/d/m (20,000 gpd/ft). Average water level contours (see Figure 5) indicated general groundwater movement toward the east, with a piezometric gradient of 0.0022 or about the same direction and rate as water in the underlying shallow aquifer. However, the water table in the alluvium varied from 2.1 to 2.7 m (7 to 9 ft) below the land surface and had an average elevation of 1,068 m (3,501 ft).

Hydrogeology at the Test Site

For this study, the alluvium aquifer is the most significant. Once it was established that there was probably an effective aquitard between the alluvium and underlying shallow aquifer, well 12070 was constructed to verify that there was no effective movement of irrigation water into the lower aquifer at the test site. Water table fluctuations and water quality analyses confirmed the existence of an aquitard between the alluvium aquifer and the shallow aquifer. This does not preclude slow, vertical leakage between the two aquifers in response to the changing head conditions.

Recharge to the alluvium and shallow aquifers is derived primarily from irrigation return flow and vertical leakage from the underlying artesian aquifer. Only about three percent of the annual recharge is estimated to come from precipitation. Considering the rainfall during 1976 and 1977 as shown in Table 4, the recharge from precipitation for that period was probably negligible. The data in Table 3 show that by late April the water level in the underlying aquifer (well 12070) has dropped to 8 m (26 ft) below the top of the casing. Following the irrigation season this water level recovered to 1 m (4 ft) by the middle of October and continued to recover through January.

The test site hydrologic cycle which illustrates rainfall, irrigation, and water-level fluctuations is shown in Figure 6. It is difficult to identify a pattern of water-level fluctuations from only one year's records. The graph obtained from the on-site water-level recorder that was installed in the alluvium aquifer probably reflects an initial decline at the beginning of the irrigation season in response to heavy pumping from the underlying aquifer. This initial decline could reflect slow downward leakage as the underlying aquifer is drawn down. It is followed by a slow recharge as a result of irrigation, reaching an overfull situation in August. This probably results in recharge to the Rio Hondo as the aquifer moves back toward equilibrium between discharge and the slow upward leakage from the recovering piezometric head of the underlying aquifer (see well 12070, Table 3). The delay between the time of irrigation and an indication of recharge of one or two months may correspond to the time required for the irrigation water to move through the unsaturated zone to the water table.

If a storage coefficient of 0.10 is assumed for that part of the aquifer in which the water table is fluctuating, then the 0.4 m (1.2 ft) of fluctuation would indicate leakage downward of 3.7 cm (1.4 in) per month. Recharge from irrigation return could be 19 cm (7.5 in) per year or 4.8 cm (1.9 in)

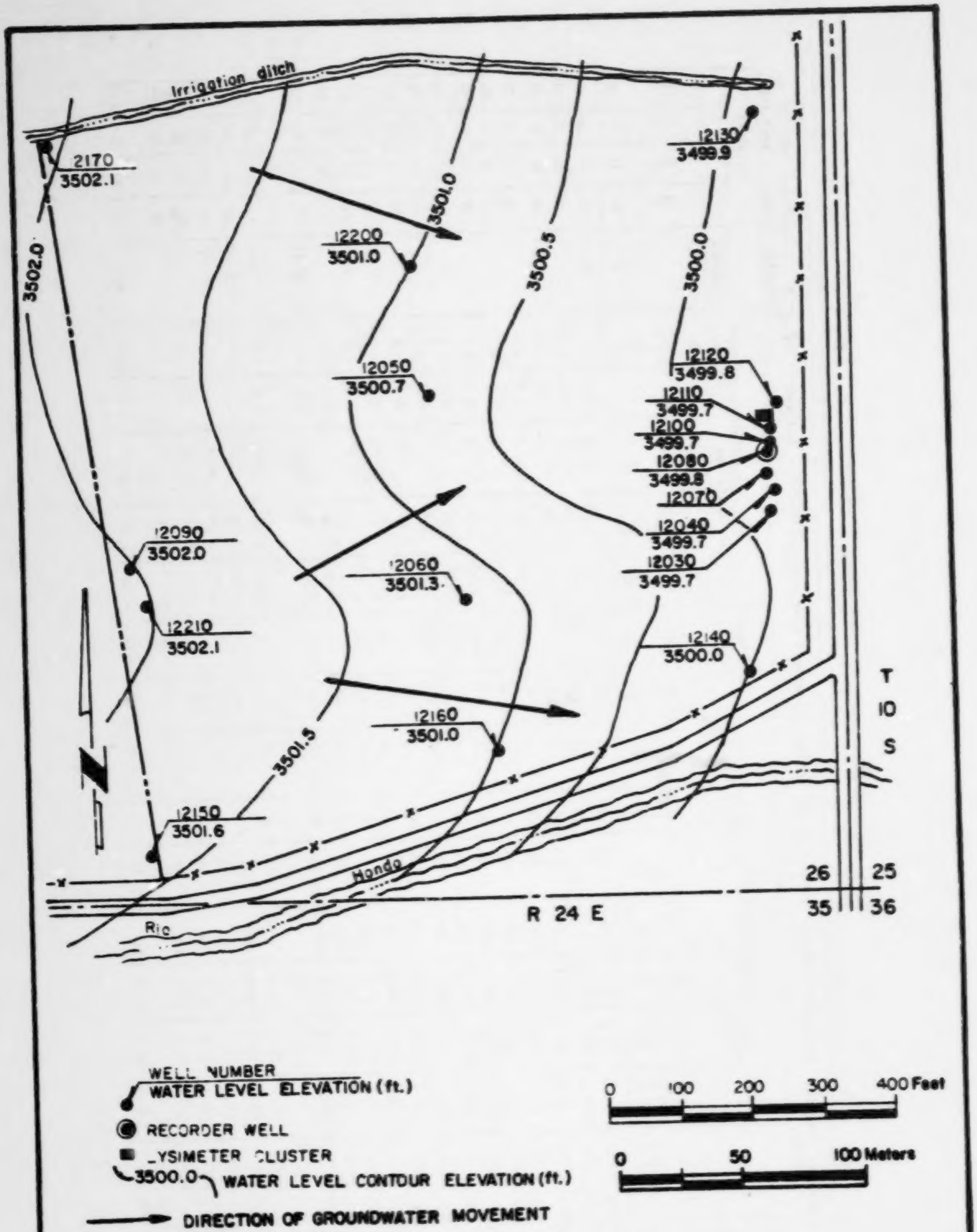
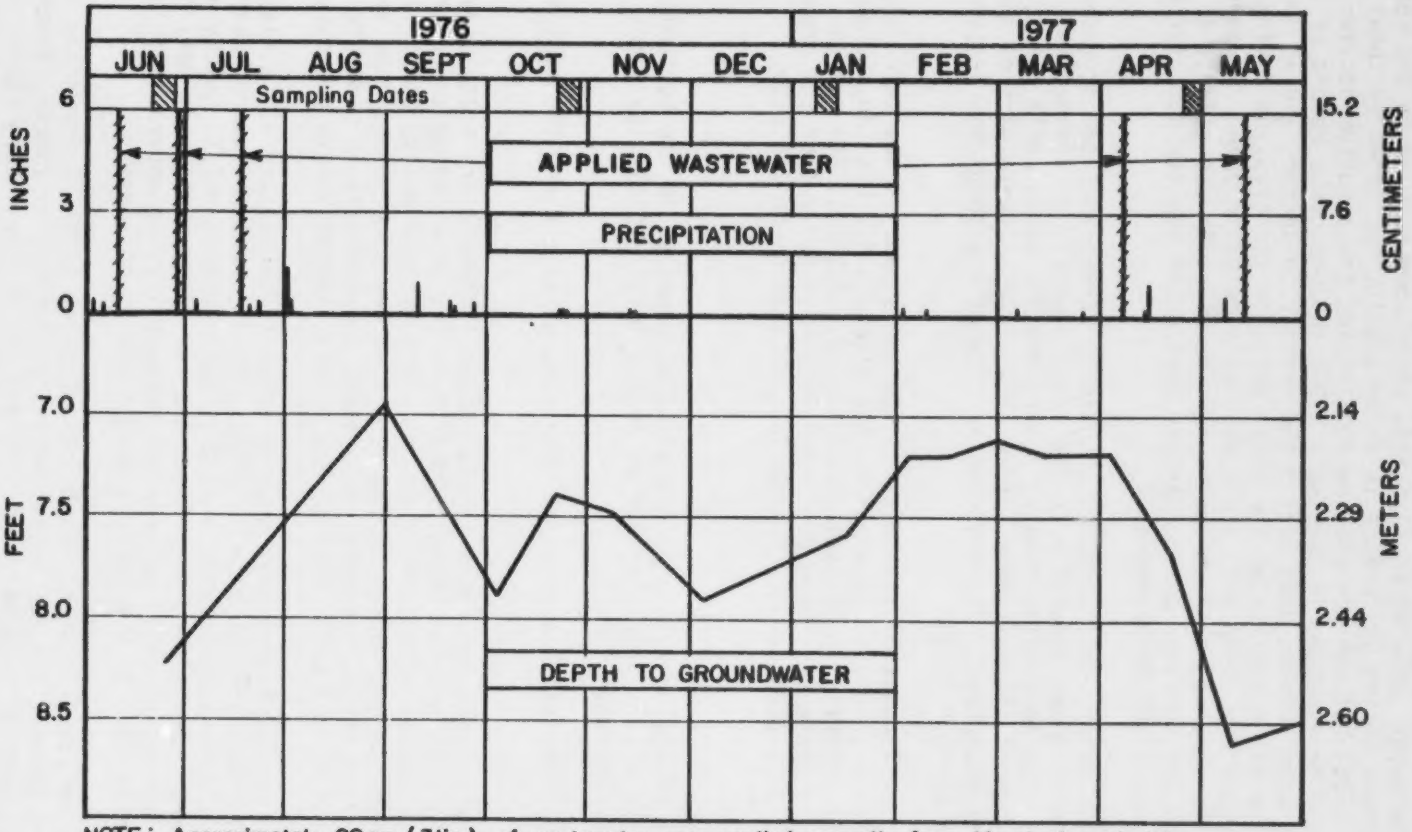


Figure 5. Test site groundwater contours.

TABLE 4. RECENT METEOROLOGICAL DATA FOR ROSWELL, NEW MEXICO

Station: ROSWELL, NEW MEXICO--ROSWELL INDUSTRIAL AIR CENTER Standard time used: MOUNTAIN Latitude: 33° 18' N Longitude: 104° 32' W
23009 Elevation (ground): 3649 feet

Month	Temperature °F							Degree Days Base 65°F		Precipitation in inches						Relative humidity, pct.			
	Averages			Extremes						Water Equivalent			Snow, Ice Pellets						
	Daily Maximum	Daily Minimum	Monthly	Highest	Date	Lowest	Date	Heating	Cooling	Total	Greatest in 24 hrs.	Date	Total	Greatest in 24 hrs.	Date	Hour 05	Hour 11	Hour 17	Hour 23
Jan, 1976	56.0	24.7	40.4	70	15	11	3	755	0	0.12	0.12	25-26	1.2	1.2	25-26	61	42	30	51
Feb, 1976	69.8	36.7	53.3	81	29	20	22	334	0	0.22	0.19	11-12	0.0	0.0		51	31	25	39
Mar, 1976	69.7	38.5	54.1	86	25	25	5	334	7	0.24	0.24	30	2.4	2.4	30	42	24	18	31
Apr, 1976	77.9	49.4	63.7	89	26	36	1	90	57	0.79	0.49	29-30	0.0	0.0		56	31	24	42
May, 1976	82.4	54.9	68.7	94	29	43	1	36	159	0.82	0.77	4	0.0	0.0		61	34	25	44
Jun, 1976	93.4	65.2	79.3	104	21	56	1	0	436	1.55	0.76	3	0.0	0.0		59	34	24	40
Jul, 1976	90.1	67.1	78.6	96	3	62	25	0	429	2.44	0.89	14	0.0	0.0		79	50	37	64
Aug, 1976	93.1	67.4	80.3	100	6	57	29	0	478	1.98	1.54	1	0.0	0.0		61	36	28	48
Sep, 1976	82.9	59.4	71.2	93	4	44	29	18	211	2.29	1.01	9	0.0	0.0		80	54	45	67
Oct, 1976	70.3	42.1	56.2	86	11	30	28	275	9	0.69	0.51	27-28	4.2	3.1	28	66	41	34	54
Nov, 1976	56.5	28.9	42.7	76	6	4	29	663	0	0.41	0.35	12-13	4.1	3.5	12-13	79	53	48	73
Dec, 1976	56.1	22.5	39.3	72	27	17	31	789	0	0.00	0.00		0.0	0.0		65	39	32	54
1976	74.9	46.4	60.7	104	Jun 21	4	Nov 29	3294	1786	11.55	1.54	Aug 1	11.9	3.5	Nov 12-13	63	39	31	51
Jan, 1977	52.5	24.7	38.5	69	26	3	9	811	0	0.07	0.04	8-9	0.4	0.4	8-9	65	45	36	58
Feb, 1977	63.0	33.4	48.2	82	21	22	1	463	0	0.36	0.20	10	0.4	0.4	25-26	61	40	28	50
Mar, 1977	68.2	35.9	52.1	83	13	23	6	393	0	0.27	0.18	26-27	0.9	0.9	5	46	28	21	37
Apr, 1977	76.7	47.9	62.3	87	27	31	4	109	34	1.25	1.01	13-14	0	0		68	40	28	54
May, 1977	87.5	59.1	73.3	101	30	50	15	0	269	2.43	1.52	31	0	0		57	30	20	37
Total, Jan-May, 1977	69.6	40.2	54.9	101	May 30	3	Jan 9	1776	303	4.38	1.52	May 31	1.7	0.9	Mar 5	59	37	27	47



NOTE: Approximately 80cm (31in.) of wastewater was applied annually from March through July. Depth to groundwater measured at well 12080.

Figure 6. Test site hydrologic cycle.

per month. The excess of recharge over leakage of 1.1 cm (0.4 in) per month would raise the water table 45 cm (1.5 ft), which corresponded to the recorder chart. Because of the difference in water quality indicated by total dissolved solids (TDS) between the shallow aquifer and the alluvium aquifer, a higher TDS would be expected in deep well 12070 in June, as a result of the poorer quality water moving down during the irrigation season, and an improvement in the water quality of the lower wells in the alluvium during the winter. Unfortunately, deep well 12070 was not sampled in June. However, all of the wells screened near the bottom of the alluvium did reflect a decrease in TDS and sulfates during January (see water quality data for wells 12043, 12030, and 12203 in Appendix B).

The average water level contours (Figure 5) showed that the groundwater flow across the site was generally to the east; however, it divided the southern part, with some water flowing toward the Rio Hondo while the remainder moved toward the northeast. Flow across the northern part of the site moved east-southeast. The groundwater flow at any point was perpendicular to the contour lines.

From the coefficient of transmissibility and slope, it was calculated that the average groundwater flow across the site was 2.1 L/s (48,000 gpd), and the average velocity in the saturated zone was 0.3 m (1 ft) per day. On an average daily basis (assuming 7.5 in/yr) about 19 percent of the groundwater flow could be considered recharge from irrigation on the site.

SOILS

The soils at the Roswell site are alluvial deposits in the bottomlands of the Rio Hondo valley characterized as nearly level, silty clay loams with moderately slow permeability.

A profile description typical of both control site B and the test site follows:

> Ap-0-32 cm (0-12.6 in); dark grayish brown (10YR4/2) dry silty clay loam, very dark grayish brown (10YR3/2) moist; weak medium and coarse subangular blocky structure; hard dry, very friable moist, sticky and plastic wet; common micro and few very fine and fine pores; many very fine and fine roots; strongly calcareous; permeability is moderately slow at 0.5 to 1.5 cm/hr (0.2 to 0.6 in/hr); abrupt smooth boundary.
>
> A12-32-47 cm (12.6-18.5 in); grayish brown (10YR5/2) dry silty clay loam, very dark grayish brown (10YR3/2) moist; weak medium and coarse subangular blocky structure; hard dry, very friable moist, sticky and plastic wet; many micro, very fine, and few fine pores; many very fine and fine roots; strongly calcareous; permeability is moderately slow 0.5 to 1.5 cm/hr (0.2 to 0.6 in/hr); abrupt smooth boundary.
>
> C1-47-62 cm (18.5-24.4 in); dark grayish brown (10YR4/2) dry clay loam, very dark brown (10YR2/2) moist; weak fine subangular blocky structure; hard dry, very friable moist, sticky and plastic wet; many micro, very fine, and few fine pores; many very fine and few fine roots; few gypsum

crystals; strongly calcareous; permeability is moderate 1.5 to 5.0 cm/hr (0.6 to 2.0 in/hr); abrupt smooth boundary.

C2-62-118 cm (24.4-46.5 in); dark grayish brown (10YR4/2) dry silty clay loam, very dark grayish brown (10YR3/2) moist; moderate fine subangular blocky structure; hard dry, very friable moist, sticky and plastic wet; many micro, very fine, and few fine pores; common very fine and few fine roots; pockets of fine sandy loam and clay loam; strongly calcareous; permeability is moderately slow 0.5 to 1.5 cm/hr (0.2 to 0.6 in/hr); wavy gradual boundary.

C3-118-158 cm (46.5-62.2 in); very dark gray (10YR3/1) dry clay, black (10YR2/1) moist; strong very fine subangular blocky structure; very hard dry, friable moist, very sticky and very plastic wet; common micro, very fine, and few fine pores; common very fine roots; slightly calcareous; permeability is very slow less than 1.5 cm/hr (0.6 in/hr); wavy and clear boundary.

C4-158-205 cm (62.2-80.7 in); very dark gray (10YR3/1) dry clay, black (10YR2/1) moist; massive; very hard dry, friable moist, very sticky and very plastic wet; common micro and very fine pores; few very fine roots; few iron mottles; slightly calcareous.

CLIMATE

Roswell has a semi-arid continental climate characterized by distinct seasons, a wide range of diurnal and annual temperatures, moderately low rainfall, and plentiful sunshine.

Climatic data for the period of the study are shown in Table 4. The annual pattern of precipitation and temperature at Roswell for a 66-year period of record is shown in Table 5.

Average annual precipitation is about 30.5 cm (12 in). The main source of moist air is the general southeasterly circulation from over the Gulf of Mexico. Nearly three-fourths of the annual precipitation falls during the growing season, May through October, mainly from brief but often intense thunderstorms. Annual precipitation totals may vary greatly, as shown by 83.6 cm (32.9 in) at Roswell in 1941, and only 11.0 cm (4.35 in) in 1956.

The snowfall season is November through April, with an annual average of 25.4 cm (10 in). Usually, snow only falls to a depth of 2 to 5 cm (1 to 2 in) in a day and does not stay on the ground long, but 38.8 cm (15.3 in) fell at Roswell in 24 hours on December 8 and 9, 1960.

Temperatures of 32^{o} C (90^{o} F) or higher occur on most days from mid-May through mid-September, but nighttime temperatures are generally 17^{o} C (30^{o} F) cooler. Extreme temperatures have been 44^{o} C (112^{o} F) at Bitter Lakes Wildlife Refuge on July 14, 1958, and -34^{o} C (-29^{o} F) at Roswell on February 13, 1905. Temperatures drop to freezing during most nights from mid-November through mid-March, but rarely does the temperature fail to reach freezing or

TABLE 5. MONTHLY TEMPERATURES AND PRECIPITATION, ROSWELL, NEW MEXICO, CHAVES COUNTY, FOR PERIOD OF RECORD 1894-1960, EXCEPT AS NOTED

Item	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Temperatures (F^{o})												
Average daily maximum	55	60	67	76	83	92	92	91	85	75	64	55
Average daily minimum	25	28	35	43	52	61	65	64	57	45	32	25
Daily mean	40	44	51	59	68	76	79	78	71	69	48	40
Extreme maximum	88	88	95	97	103	110	110	105	103	94	87	84
Extreme minimum	-19	-29	-5	17	28	45	53	48	33	19	-6	-10
Precipitation												
Average (inches)	0.42	0.48	0.54	0.80	1.18	1.36	2.00	1.72	1.84	1.17	0.59	0.53
Average days 0.10 inch or more (no.)*	2	1	1	2	2	2	4	3	3	2	1	1
Average snowfall (inches)	2.6	2.3	1.0	1.0	T	0	0	0	0	0.1	1.1	2.8

*Period of record 1931-1960.

T = Trace, less than 0.05 inch.

Source: National Climatic Center, Asheville, North Carolina.

above during the day, and seldom does the temperature drop to -18° C (0° F). The average freeze-free season is six months, from late April to late October.

Relative humidity in most of the county is similar to that at Roswell, averaging about 50 percent, and ranges from 70 percent in the early morning to 30 percent in the late afternoon. Lowest humidities occur in the spring.

Evaporation measured by a Class A pan at Bitter Lake Wildlife Refuge averaged 244 cm (96 in), two-thirds of which occurred during May through October.

Average annual wind speed at Roswell Airport is 16 km (10 mi) per hour. The wind blows from the southeast quadrant 40 percent of the time, and it is strongest in spring. Strongest winds, those above 39 km (24 mi) per hour, occur with greatest annual frequency from the west quadrant. The general north-south orientation of the Pecos River Valley probably increases the frequency of winds from those directions at Roswell.

LAND USE

Irrigated farming in this artesian basin began on an extensive basis about 1900 and is an important land use. Most of the water used for irrigation is obtained by pumping from the underground artesian aquifer. The irrigated area comprises approximately 40,900 ha (101,000 acres). Although this is a relatively small percentage of the total land area, it contributes significantly to the economy of the county. Alfalfa and cotton are the most extensive crops, but grain sorghums, small grains, corn, and pecans are also produced. Sugar beets and vegetable crops have also been grown to a very limited extent with satisfactory results.

Prior to organization of Chaves County and the expansion of irrigation, the lands comprising this county were used principally for grazing. Ranching is still an important agricultural enterprise, and in 1968 most of the county's 157,000 cattle and 149,000 sheep were supported by rangeland.

Another important land use is for wildlife and recreation. The rangeland areas of the county provide suitable habitat for many species of wildlife. The limestone hills in the western part of the county, in particular, provide good habitat for big game animals (New Mexico Council, 1975).

Agricultural Practices and Productivity

Both control and test sites are irrigated by the ridge-and-furrow method from an irrigation supply ditch, using siphon tubes. The control site irrigation water supply is from wells in the alluvium. The test site water supply is municipal wastewater from a trickling filter treatment plant that includes an oxidation ditch and chlorination.

The hydraulic loading from irrigation is approximately 80 cm (31.5 in) per year. The irrigation season is generally from March through July for crops such as corn and grain sorghum and March through September for alfalfa. The seasonal precipitation is shown in the climatological section of this report (Tables 4 and 5).

Cropping and cultural history for both sites is:

1976 - Corn
1972-1975 - Alfalfa
1966-1972 - Corn or grain sorghum

Crop yields for both sites were:

Corn - 40 metric tons/ha (18 tons/acre) as 70 percent moisture silage/yr
Grain sorghum - 50 quintal/ha (4,461 lb/acre) as grain/yr
Alfalfa - 14 metric tons/ha (6.2 tons/acre) as hay/yr

Fertilizer history for both sites is:

Grain sorghum and corn: nitrogen - 78 kg/ha/yr (68 lb/acre/yr)
Alfalfa: phosphorus - 38 kg/ha/yr (33 lb/acre/yr)

Pesticides which have been applied are parathion, dicamba, oxydisulfoton, and prometryn. The rates of application are not known.

SECTION 5

PLANT OPERATION AND COSTS

WASTEWATER TREATMENT

Secondary treatment (trickling filter) has been used since 1944. The plant capacity was expanded in 1961 and again in 1974. In 1974 an oxidation ditch and chlorination were added to the trickling filter process. The present process consists of the following: pre-aeration, primary settling, trickling filter, oxidation ditch, final settling, and chlorination. The effluent is discharged through a 5.6-km (3.5-mi) pipeline by gravity-flow. Irrigation water is removed from the pipeline as required by the farmers. That part not used is discharged primarily to the Bitter Lakes (a Wildlife Refuge) or occasionally to the Rio Hondo.

In 1975, the air base plant was abandoned and the flow diverted to the Roswell Wastewater Treatment Plant. No known problems exist regarding toxic industrial wastes. However, the Glover packing plant discharges pretreated wastes to the system.

The present waste flow is about 175 L/s (4 Mgal/d). The sludge is spread on drying beds located at the plant. The dried sludge is then stockpiled at the plant for use by local farmers. The system is owned and operated by the City of Roswell.

WASTEWATER CONSTITUENTS

The wastewater characteristics are typical of domestic waste (Table 6).

IRRIGATION WITH WASTEWATER

Much of the effluent has been used for irrigation during the irrigation season at least since 1944. The City has several meters installed to measure the amount of effluent withdrawn and sells the water on a contract basis. Wastewater is also pumped to the Roswell Country Club, where it is used to irrigate a golf course. Several of the farmers mix the wastewater with groundwater prior to irrigation. The extent of irrigation with wastewater is shown in Figure 7. The water from the Rio Hondo is also used for irrigation, and it occasionally contains effluent.

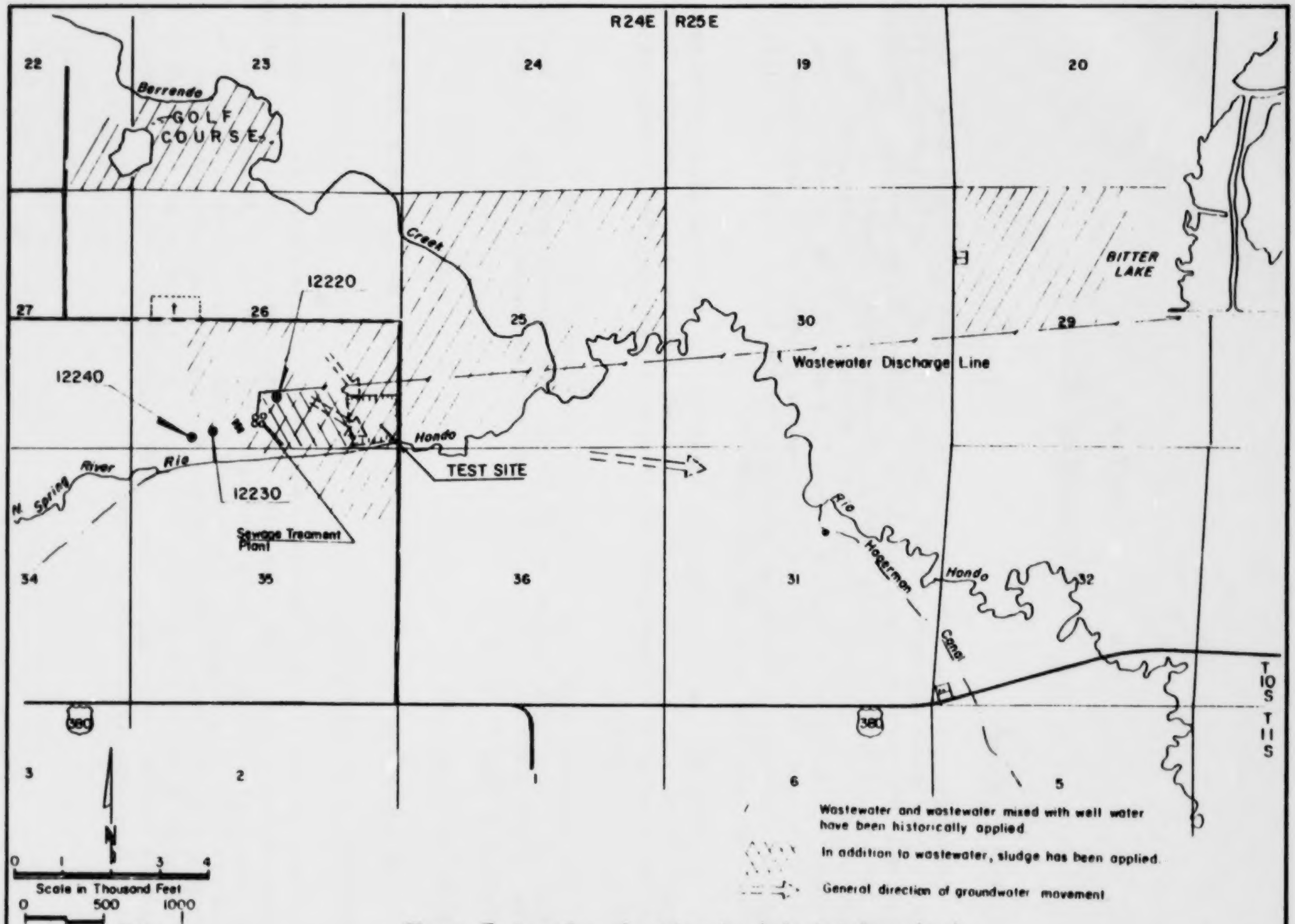


Figure 7. Location of wastewater irrigated farm land.

TABLE 6. MONTHLY AVERAGE WASTEWATER CHARACTERISTICS*

Month	BOD (mg/L)		Suspended Solids (mg/L)	
	Raw	Final	Raw	Final
Jan. '74	136	32	251	54
March	148	35	227	29
May	202	45	300	48
July	154	23	342	27
Sept.	128	25	295	41
Nov.	132	37	270	34
Jan. '75	184	19	234	24

* From Sewage Treatment Plant Logs.

CAPITAL AND OPERATING COSTS

The initial cost of the Roswell Sewage Treatment Plant was about $1,500,000 in 1944. The 1961 modification cost an estimated $250,000 and was financed by a grant using the sewage treatment plant revenues as the City's share. The 1974 modification of the sewage treatment plant cost $998,000. It was financed by a 50 percent EPA grant, 25 percent state grant, and 25 percent sewage treatment plant revenues. As of April, 1977, Step 1 of the 201 program was in progress for enlarging the sewage treatment plant.

The operations and maintenance (O & M) costs from the City's 1976-77 operating budget were as follows:

Labor (wages, salaries, taxes, FICA overhead, and some benefits. Some additional, undefined benefits were not included.)	$105,676
Utilities	24,000
Repairs, Replacement, Maintenance	7,700
Telephone	600
Materials and Supplies	18,000
Vehicle Maintenance	1,000
Total Annual O & M	$156,976

In addition to revenues from sewage-use charges, the City also charged for metered effluent used by the farmers. An estimated 2,775,000 m^3 (2,250 acre-ft) was sold during 1977 at a cost of $5.00 per 1,233 m^3 (1 acre-ft), providing approximately $11,250 of income to the City.

SECTION 6

RESEARCH METHODS

WELL CONSTRUCTION AND LOCATIONS

Well Construction

All sampling wells were drilled with either a mud-rotary or cable-tool rig. In order to keep contamination of the aquifer material to a minimum, only clean Roswell city water was used for drilling. If it was necessary to use bentonite mud in the drilling fluid to keep the hole from caving, the hole was flushed out with city water just before reaching the depth where the screen was to be placed. The drilling was then continued with city water until the proper depth was reached, and the screen and casing were immediately set. A sand pack material was placed around the screen and several feet above the top of the screen. The gravel pack was clean, washed silica sand from Arkansas. The hole was sealed above the gravel pack from downward moving water by grouting with bentonite pellets. The remainder of the hole was backfilled with native material.

All polyvinyl chloride (PVC) screens and PVC casings were schedule 40 and 5 cm (2 in) in diameter except for the recorder well, which was 15 cm (6 in) in diameter. The screens were factory-slotted with a slot opening of 0.076 cm (0.030 in).

The PVC casing was cut at about 15 cm (6 in) above the ground surface, and a threaded PVC cap was placed on top of the casing. The area around the casing was filled with either bentonite pellets or powder for a radius of about 30 cm (12 in) and about 13 cm (5 in) deep, and the bentonite was covered with tamped soil. In order to protect the above-ground portion of the casing, a steel pipe, 0.6 m (2 ft) in length and about 25 cm (10 in) in diameter, fitted with a hinged, lockable top, was centered over the top of the casing and pushed about 0.3 m (1 ft) deep into the ground. A typical well completion is shown in Figure 8.

The following procedure was used to decontaminate the wells. After completing each sampling well, 76 liters (20 gallons) of 1 percent of calcium hypochlorite solution was poured into the wells. The well was then surged, and the chlorinated water was recirculated by a centrifugal pump to thoroughly wash down the side of the PVC casing. Prior to sampling, the well was pumped and water discarded until the pumped water showed no residual chlorine by the ortho-tolidine test.

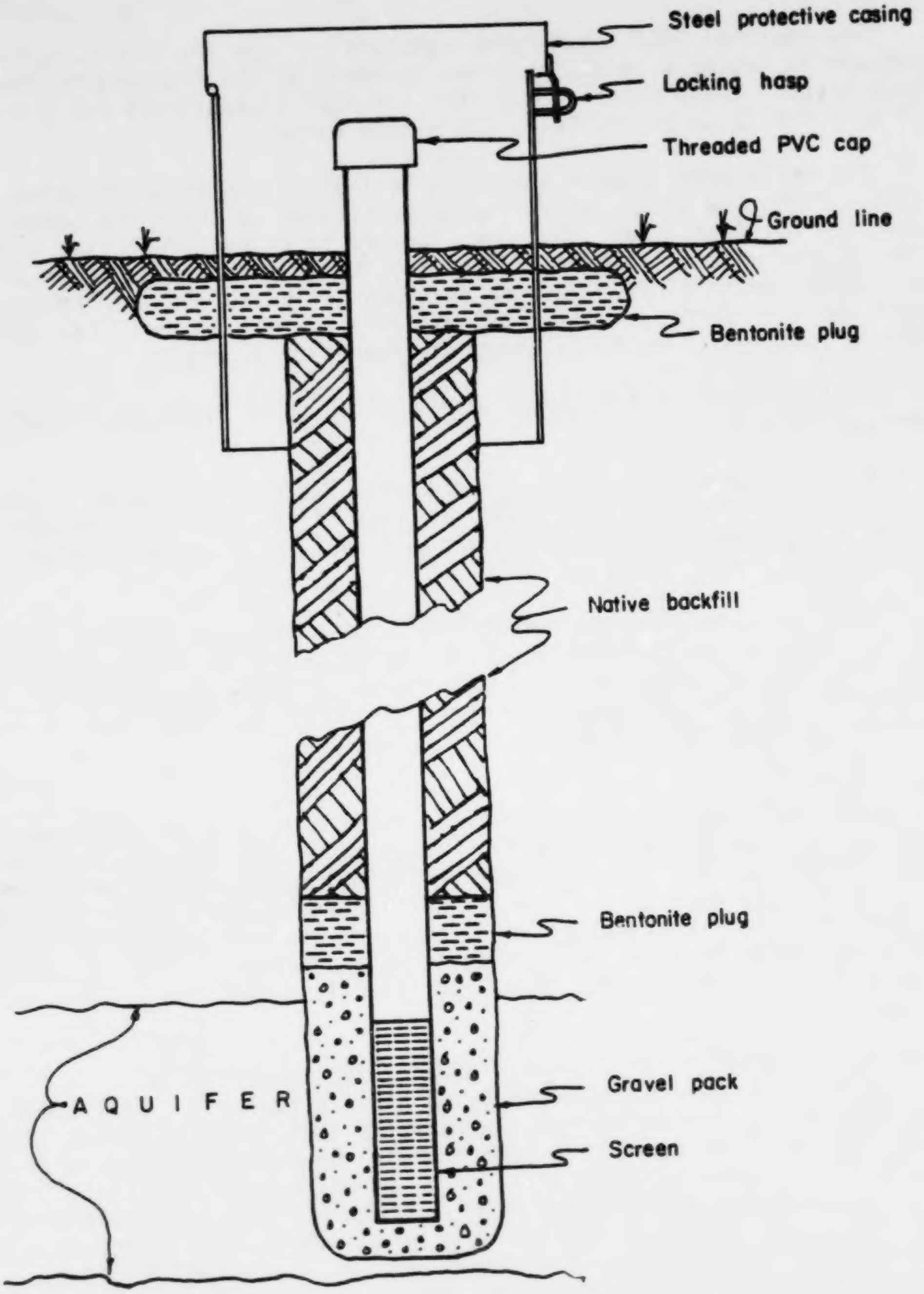


Figure 8. Typical well completion.

Well Locations

The regional 1969 water-level contours for the shallow alluvial aquifer indicate an easterly to southeastern movement of the groundwater toward the Pecos River. These water levels show seasonal fluctuations but are generally 1.5 to 4.6 m (5 to 15 ft) below the ground surface.

Six wells were located above the test site, and three of these, wells 11030, 12220, and 12230, were sampled to provide upstream and background water quality data. Well 11030 was located in an area irrigated with artesian aquifer water. However, it was subsequently determined that well 12220 was located downhill from an area that was irrigated with a mixture of wastewater and groundwater. Well 12230 was located in a nonirrigated pasture. The map location of wells is shown in Figures 5, 7, and 9.

Two wells, 11050 and 11060, were located in an artesian irrigated field near the Pecos River.

All on-site sampling wells except well 12070 were located to provide information on the upper and lower portions of the shallow groundwater aquifer as the groundwater moved across the site. The on-site groundwater-level contours are shown in Figure 5.

Wells were not located immediately downstream from the test site because the Rio Hondo is on the southern side, and the land to the east was irrigated with a mixture of wastewater and groundwater. The wells located on the eastern boundary of the site provided information on water quality as the groundwater moves off the site.

Well 12070--

Well 12070 was constructed using a mud-rotary rig and was screened at a depth of 30 to 32 m (100 to 105 ft). Because of the difference in water-level elevations from the shallower wells (all other on-site wells were screened at less than 10 m (33 ft)), well 12070 appeared to be in an artesian aquifer that was not connected with the upper shallow groundwater aquifer. The fluctuations in water-level elevations are shown in Table 3, and it can be seen that the water level rose significantly during the nonirrigation season.

Wells 12041, 12042, 12043, 12201, 12202, 12203, and 12090--

These wells were constructed using a cable-tool rig. Well 12090 was completed in the typical manner, while wells 12041, 12042, 12043, 12201, 12202, and 12203 were multiple completions. Because using the cable-tool rig resulted in a large diameter drill hole, it was possible to install three 5 cm (2 in) diameter wells in two holes. As an example, the deepest screen, well 12043, was installed first in the typical manner, with gravel pack and a bentonite seal above. Then the screen and casing for well 12042 was installed in the same hole with gravel pack and a bentonite seal. Finally, the screen and casing for well 12041, the shallowest well of this multiple completion, was installed, and the well was completed in the typical manner. Wells 12201 - 12203 were installed similarly. Figure 10 provides a cross-sectional view of the test site wells.

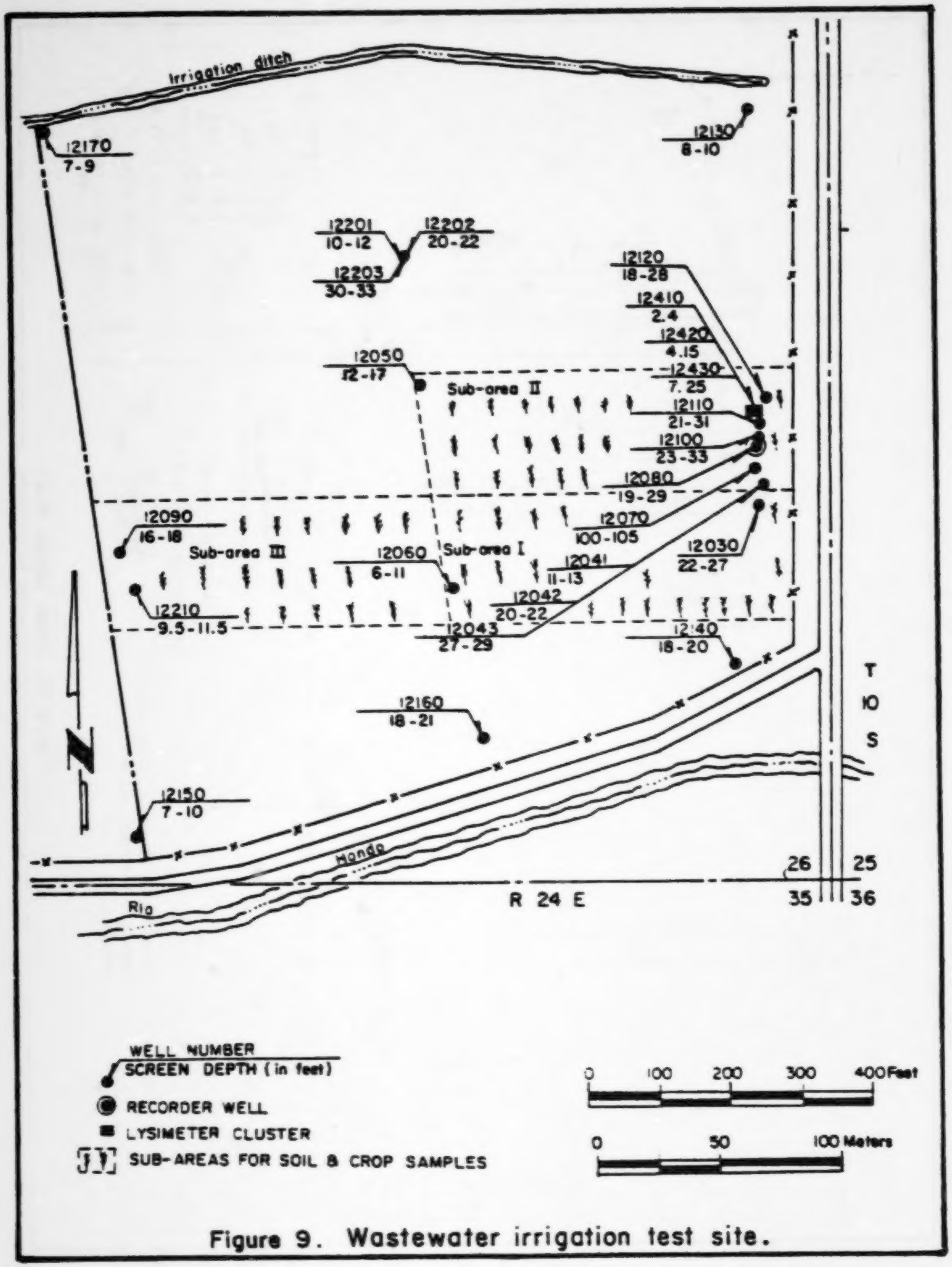


Figure 9. Wastewater irrigation test site.

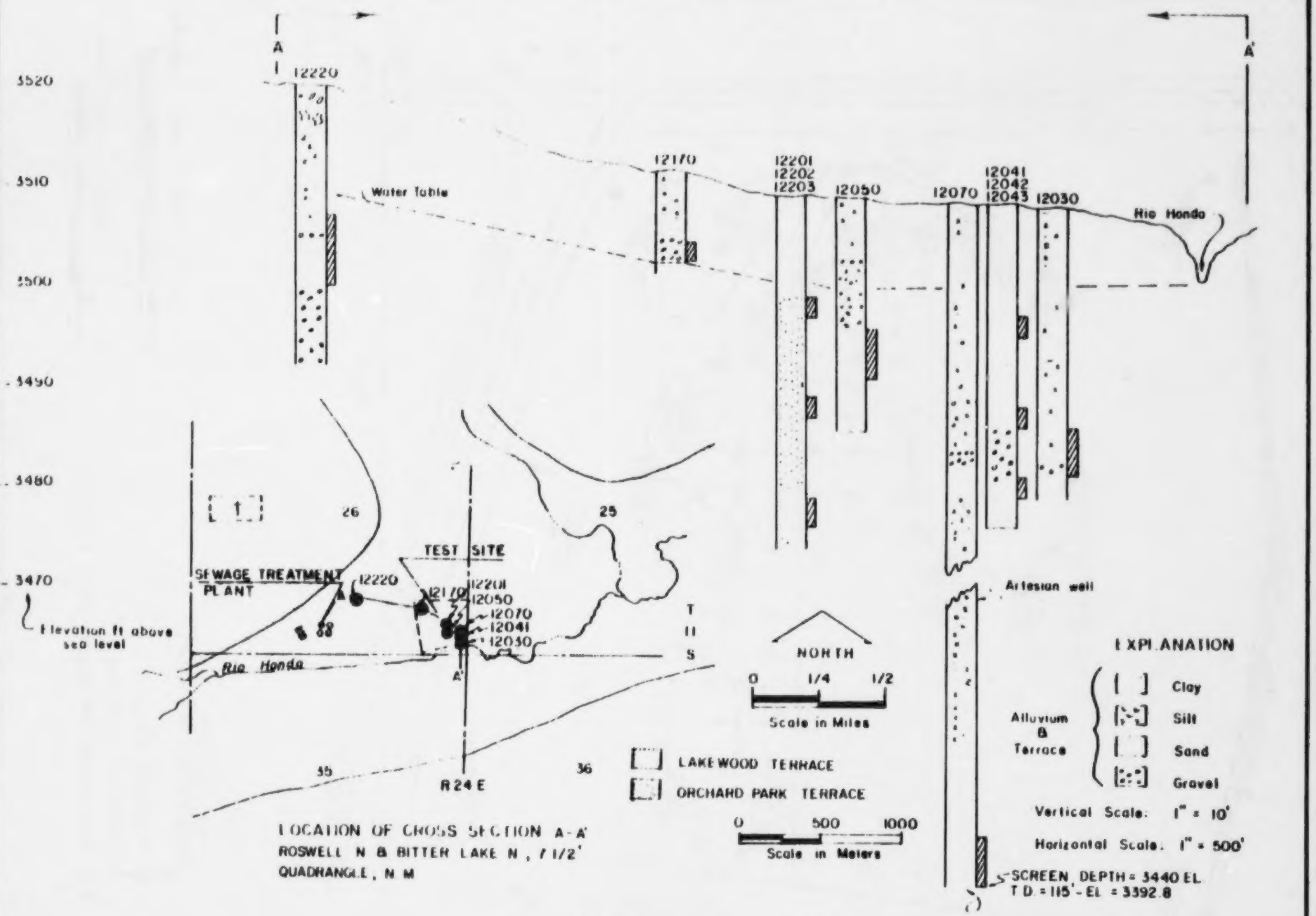


Figure 10. Cross section A-A'.

Lysimeter Installation

The lysimeter cluster was located on the eastern edge of the test site (Figure 9). A 10 cm (4 in) diameter hole for each of the three lysimeters was drilled (Figure 11).

Prior to installation, each porous lysimeter cup was pretreated by the following procedure: A 300 mL volume of 10 percent Calgon (sodium hexametaphosphate) solution was pulled through each lysimeter cup using a negative pressure of 12.7 cm (5 in) of mercury. This solution was blown out of the lysimeter using a positive pressure. The procedure was repeated once using a 10 percent hydrochloric acid solution and again using distilled water. The pretreated lysimeters were then ready for installation.

A silica flour (crushed silica sand 140 mesh) and distilled water slurry was mixed, and a small portion was poured into the lysimeter hole to keep the base of the cup from contact with the native sediment. The lysimeter assembly was lowered into the hole, and additional silica slurry was poured around the lysimeter to cover the ceramic cup and about 10 cm (4 in) of the teflon body. Material dug from the hole and approximately from the same depth was replaced and lightly tamped. This backfill material was followed by a bentonite plug composed of a very viscous slurry of powdered bentonite and distilled water. The bentonite plug was covered with backfill until the hole was filled.

Surface completion was similar to that of the water sample wells, except a steel box was used to house the lysimeter vacuum bottles.

SAMPLING

Soil Sampling

An area of approximately 3 ha (5 acres) each at control site B and at the test site that typically and homogeneously represented the soil type and the crop being grown was selected for sampling. This selection was coordinated between the agronomist, the groundwater geologist, and the engineer to ensure that the soil, plant, and water samples would be from the same area.

The selected area was subdivided into three approximately equal-sized sub-areas, and each sub-area was used as a sample unit for soil and plant sampling and analysis. Since the area was selected for its homogeneity of soil type and crop condition, the sub-areas were assumed to be representative of conditions for the area as a whole.

Composite soil samples were collected from each sub-area by combining all sub-samples of the same depth. Location of individual sample points within the sub-area followed a random, zigzag pattern. Sample cores were taken from the following depths: 0 to 2 cm (0 to 0.8 in); 2 to 4 cm (0.8 to 1.6 in); 9 to 11 cm (3.5 to 4.3 in); 29 to 31 cm (11 to 12 in); 95 to 105 cm (37 to 41 in); and 205 to 305 cm (81 to 120 in). This sampling regime was followed twice during the study period, once during the warm season (July 2, 1976) and once during the cool season (January 6, 1977). Composite soil

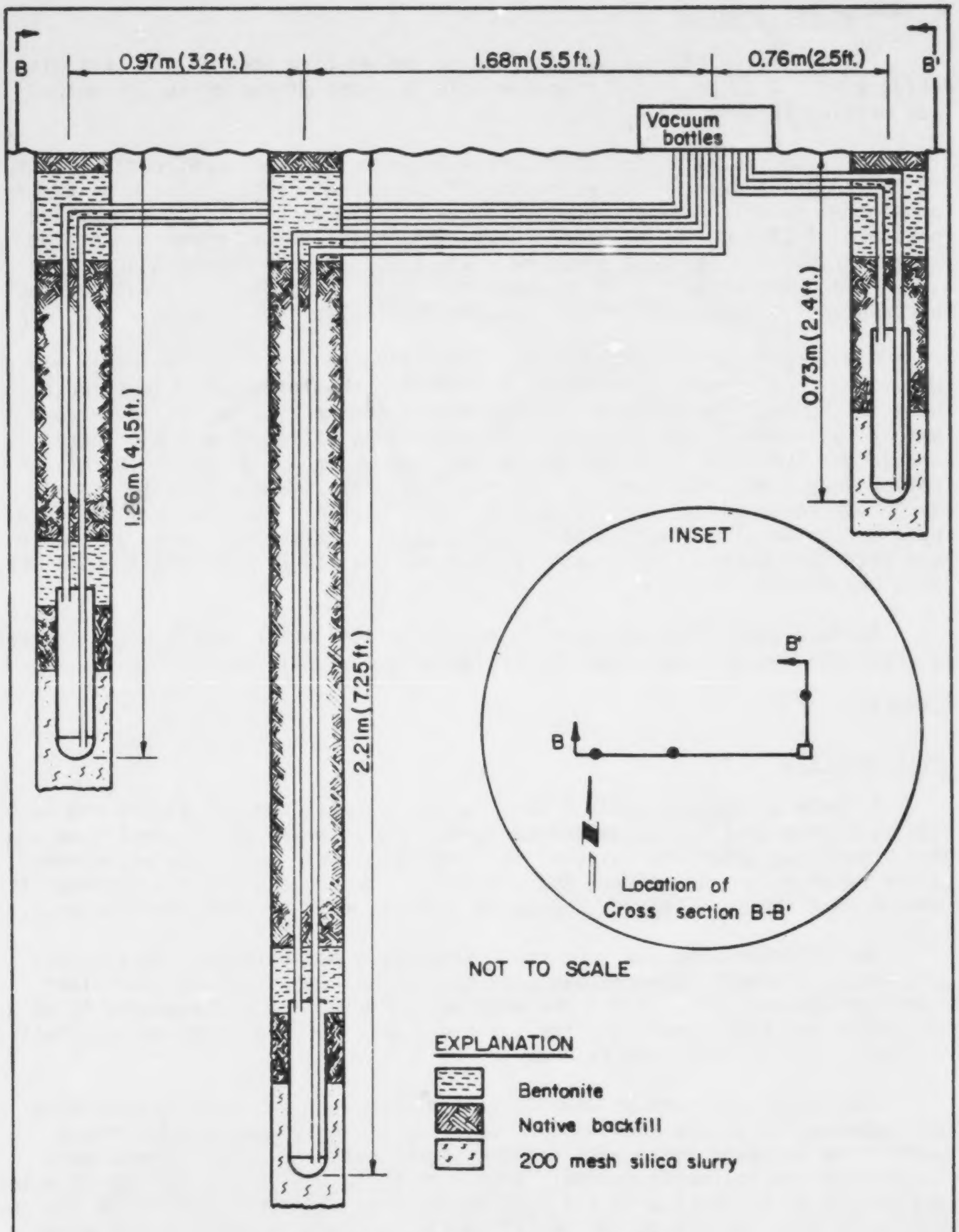


Figure 11. Lysimeter installation.

samples were stored in sealed plastic bags and transported on wet ice to the laboratory.

Plant Sampling

Composite plant samples were collected in a similar manner as for soil samples.

Corn crop samples were taken when the plant was between tasseling and silk initiation. During the vegetation stage, the entire leaf at the ear node was sampled. Corn grain samples were taken at maturity on the test site only.

Virus Sampling

Water--

Water was collected at the sampling wells and at the effluent discharge of the treatment plant by pumping into polyethylene-lined 208 L (55 gal) drums and transported to the field laboratory by truck. The wells, pump, hoses, and drums were sterilized with calcium hypochlorite solution and then rinsed until no residual chlorine was detected by the ortho-tolidine test prior to taking samples.

At the field laboratory viruses were concentrated by using a virus concentrator as illustrated in the 14th edition of Standard Methods, Section 913 A. The concentrator utilizes the general principle of acidification of the sample, adsorption of the viruses onto a filter, and subsequent readjustment of the pH allowing elution of the viruses into the concentrated sample.

The final concentrate was air-shipped to the assay lab on dry ice.

Crops--

The corn ears were hand-collected at the dough stage of growth development, left in the shuck, bagged in plastic, placed on ice, and air-shipped to the assay lab.

Virus Assaying Procedures

Water--

In the laboratory the water samples were assayed for viruses, and neutralization tests were performed to identify the viruses by using buffalo green monkey kidney (BGMK) cell monolayers and human embryonic lung (HEL) cells for cytopathic effect (Lenette, 1969).

Samples exhibiting cytotoxicity were retested after centrifugation at 3,000 rpm for ten minutes, by filtration through a 0.45 μm filter, and two hours of adsorption at 37^{0} C (99^{0} F) during continual rotation.

If plaques became visible, they were counted, plucked, and grown for identification in either BGMK or HEL cells, depending on the cell line in which they were first isolated.

Crops--

Corn samples were processed according to the following procedures:

Control site samples--The surface of 24 ears of corn was washed with 10 liters of pH 10.5 glycine. The wash was neutralized with pH 2 glycine. Two liters of neutralized wash were adjusted to 0.003 M aluminum chloride and neutralized with 1 M sodium carbonate. Then 30 mL of floc was collected by centrifugation. The floc was mixed with 30 mL of fetal calf serum (FCS) + 1 M glycine, pH 11.5. The sample was centrifuged, and the supernatant was neutralized with 1 M, pH 2 glycine. The neutralized supernatant was reduced in volume to 10 mL by hydroextraction and was dialyzed against phosphate-buffered saline (0.01 M sodium phosphate) and assayed.

To analyze for viruses in the crop tissue, four liters of kernels were obtained. Two liters were blended with two liters of pH 11.5 glycine. The final pH of the sample was 10.0. The mixture was clarified by passing through gauze, neutralized, made isotonic, and assayed. Attempts were made to concentrate aliquots of this extract by membrane filtration and flocculation, but they proved unsuccessful.

Test site samples--The surface of 24 ears of corn was washed in two liters of pH 10.5 glycine. The wash was neutralized with pH 2 glycine, and final volume was 2,800 mL. The sample was adjusted to 0.003 M with aluminum chloride and neutralized with 1 M sodium carbonate. Then 30 mL of floc was collected, mixed with 30 mL of FCS + 1 M glycine, and centrifuged. The supernatant was neutralized with 1 M glycine, reduced in volume to 10 mL by hydroextraction, and dialyzed against buffered saline.

To analyze for viruses in the crop tissue, the kernels from 12 ears of corn were mixed with two liters of pH 10.5 glycine, blended, and clarified through gauze. The clarified sample was neutralized, made isotonic, and assayed.

Both control and test samples were assayed on buffalo green monkey (BGM) cells by the agar overlay method. The ratio of volume to area of cell monolayer used for assay was 0.1 mL of sample per 7.5 cm^2 of cell monolayer. Additionally, 100 mL of crop tissue extract from control and from test samples were assayed by allowing the samples to adsorb to 375 cm^2 of monolayer cells.

CHEMICAL AND BIOLOGICAL ANALYSES

Samples collected in the field at the control and test sites were either analyzed at the field laboratory or returned to the laboratory in Oklahoma City, Oklahoma, for analyses. The time-critical parameters were analyzed in the field as soon as the samples were collected. For those samples designated for later laboratory analyses the standard methods for preservation relevant to the parameter to be analyzed were employed. In the following sections the methods used in the analyses of water, soil, and plant samples are presented in sequence. Field methods are discussed prior to laboratory methods. A summary is given in Table 7 of the field method changes that were made during the sampling program to overcome equipment and methodology

TABLE 7. SUMMARY OF FIELD METHODS

Analysis	Sampling Trip			
	Roswell I	Roswell II	Roswell III	Roswell IV
Alkalinity (Total)	Potentiometric Titration	Potentiometric Titration	Potentiometric Titration	Potentiometric Titration
Ammonia	Probe	Probe	Probe	Probe
BOD	Probe	Probe	Probe	Probe
Chloride	Probe	Probe	Titration	Titration
Coliform (Total)	Membrane Filter	Membrane Filter	Membrane Filter	Membrane Filter
Coliform (Fecal)	Membrane Filter	Membrane Filter	Membrane Filter	Membrane Filter
Conductance	Specific Conductance Meter	Specific Conductance Meter	Specific Conductance Meter	Specific Conductance Meter
D.O.	Winkler	Winkler	Winkler	Winkler
Nitrate	Probe	Probe	Cadmium Reduction	Cadmium Reduction
Nitrogen (Kjeldahl)	Digestion & Probe	Digestion & Probe	Digestion & Probe	Digestion & Probe (Modified)
Orthophosphate (Soluble)	Single Reagent	Single Reagent	Single Reagent	Single Reagent
pH	pH Electrode	pH Electrode	pH Electrode	pH Electrode
Phosphorus (Soluble)	Filtration, Digestion & Single Reagent	Filtration, Digestion & Single Reagent	Filtration, Digestion & Single Reagent	Filtration Digestion & Single Reagent
Phosphorus (Total)	Digestion & Single Reagent	Digestion & Single Reagent	Digestion & Single Reagent	Digestion & Single Reagent
Sulfide	Probe no Preservative	Probe no Preservative	Probe no Preservative	Probe with Preservative
Sulfate	Probe	Turbidimetric	Turbidimetric	Turbidimetric

problems.

Methods for Analyses of Water

Field Analyses--

Alkalinity (total)--Water samples were titrated with a 0.02 N sulfuric acid solution to an end point of pH 4.5. An exactly prepared 0.02 N solution of sodium carbonate was used to standardize the sulfuric acid and was used in spiking water samples (APHA, 1976).

Ammonia--Ammonia analyses were performed with the use of an ammonia electrode. A standard curve was constructed from 1000, 100, 10, 1, and 0.1 mg/L solutions of stock ammonium chloride. The samples and standards were treated identically. The electrode was immersed into the sample, and 10 N sodium hydroxide was added to raise the pH. The millivolt reading was recorded, and the ammonia concentration was determined directly from the calibration curve (Orion IM, 1975a, and Bremner, 1972).

Biochemical oxygen demand--Dissolved oxygen (DO) in water samples was determined with a DO meter prior to setting up biochemical oxygen demands (BOD$_5$). The meter was air-calibrated with an aneroid barometer according to manufacturer's instructions. Air calibrations were periodically checked against the Winkler method. The samples were diluted with aerated dilution water according to the results obtained from initial experimentation. In some samples no dilutions were required. The initial DO was measured directly in the BOD bottle. The bottles were then carefully glass-stoppered and plastic caps placed over the mouths of the bottles to prevent loss of water from the water seal. The samples were prepared in duplicate and incubated at 20° C in the dark for five days. The final DO was also measured with the probe. Samples containing chlorine were treated with sodium thiosulfate to eliminate the chlorine and then seeded with 24-hour-old domestic wastewater. Glucose-glutamic acid checks were performed to observe the efficiency of the BOD procedures (APHA, 1976).

Coliform (total)--Field samples were collected in sterile glass bottles. Samples were thoroughly mixed, and 1 mL was taken with a sterile pipette and passed through a 0.45 μm Gelman filter. Beginning with sampling rounds three and four, one 50 mL sample was also run. All equipment was sterilized by immersion in boiling water. The filter was aseptically placed on a filter pad containing 2 mL Endo Broth in a 50 x 12 mm plastic petri dish. The dishes were placed into a whirlpac plastic bag, inverted, and incubated at 35° C for 24 hours in a bacteriological incubator. The typical coliform colonies counted had a pink to dark red color with metallic surface sheen (APHA, 1976).

Coliform (fecal)--The procedure was identical to that for total coliforms with the exception of medium. The medium used was mFC, and plates were not inverted. Plates were incubated at 44.5° C for 24 hours. Typical coliform colonies were small and blue (APHA, 1976).

Conductivity--Determination of specific conductance was performed using a conductivity meter. Using a potassium chloride solution of known conductance, the meter was calibrated prior to running analyses. Specific conductance values were corrected to 25° C by using multiplication factors (APHA, 1971).

Dissolved oxygen--At the well site, immediately after pumping the well, dissolved oxygen was measured by the azide modification of the Winkler method. One Hach powder pillow each of manganous sulfate, alkaline-iodide-azide, and sulfamic acid was added to the water sample. The sample was then brought to the field laboratory and titrated with phenylarsine oxide (PAO) using a starch indicator (APHA, 1976).

Nitrate nitrogen--Samples from rounds one and two were analyzed for nitrate with the use of the nitrate electrode. The probe was immersed in the sample, and the final millivolt reading was recorded. Nitrate concentrations were determined from a standard curve prepared from standards serially diluted from a potassium nitrate stock solution.

Due to the inability to recover spikes and uncontrolled drift in millivolt readings in certain samples, the nitrate probe was replaced with the cadmium reduction column method for sampling rounds three and four. The samples were flocculated and/or filtered through a 0.45 μm Gelman filter prior to analyses. An aliquot of sample was passed through a column containing granulated copper-cadmium to reduce nitrate to nitrite. Columns were reactivated between field trips and at other times when efficiency dropped. The nitrite (that originally present plus reduced nitrate) was reacted with the color reagent to form a highly colored azo dye, which was measured spectrophotometrically at 420 nanometers (nm). The nitrite was then determined in the sample and subtracted from the initial value to obtain nitrate (USEPA, 1974; Orion IM, 1975b; and Orion IM, 1976c).

Nitrogen (total and soluble organic)--A micro-Kjeldahl digester and an ammonia electrode were used for analyses. Procedural changes were made throughout the field trips in an attempt to correct the problem of not obtaining total nitrogen recovery. A 50 mL aliquot of sample (filtered for soluble, not filtered for total) was boiled in the presence of concentrated sulfuric acid, potassium sulfate, and mercuric sulfate, and evaporated one-half hour past the disappearance of sulfurous acid fumes. Rounds one, two, and three samples were analyzed by adding 10 N sodium hydroxide to the sample and recording the millivolt reading from the ammonia probe. For the first three rounds, the mercury interference in the digestion reagent was not identified before testing for ammonia. This resulted in an ammonia-mercury complex formation and low nitrogen results. Experiments in the laboratory showed that addition of 2 N sodium iodide with the 10 N sodium hydroxide did not effectively eliminate the mercury interference. Beginning with round four, two major changes were made: 1) Hengar crystals, which are selenium coated, replaced mercury as the catalyst and 2) samples were partially neutralized with sodium hydroxide and allowed to cool in an ice bath prior to ammonia analyses to compensate for heat gained from addition of the sodium hydroxide to acid. Excellent results were obtained, using the final revised procedures (Orion IM, 1975a, and Bremner, 1972).

Orthophosphate (soluble)--Orthophosphate phosphorus was determined by the single reagent method. Samples were filtered through a 0.45 μm Gelman filter. The pH of the sample was adjusted to 7.0 ± 0.2 with sodium hydroxide. Ammonium molybdate, antimony potassium tartrate, and ascorbic acid color reagent were added to the sample and read in the manner described for total phosphorus (USEPA, 1974).

pH--Hydrogen ion concentration (pH) was determined by use of a glass combination pH electrode. The meter was calibrated for pH determinations by using buffers of pH 4, 7, and 10 (APHA, 1976).

Phosphorus (total)--Phosphorus was determined by the single reagent method. Sulfuric acid (11 N) and ammonium persulfate were added to the samples. Samples were boiled gently followed by pH adjustment to pH 7.0 ± 0.2 with sodium hydroxide. Ammonium molybdate, antimony potassium tartrate, and ascorbic acid color reagent were added to the samples. The blue color formed was read at 640 nm using a spectrophotometer. The phosphorus concentration was determined from a standard curve that was prepared from serial dilutions made from a stock phosphorus solution (USEPA, 1974).

Sulfide sulfur--Analyses for sulfide were made with a sulfide electrode. Procedural changes involving sulfide anti-oxidant buffer (SAOB) and standards were a result of additional research by Orion (Orion IM, 1976a).

Rounds one, two, and three samples were brought to the field laboratory, where an aliquot of sample was added to an equal volume of 50 percent SAOB. The SAOB contained sodium hydroxide, sodium salicylate, and ascorbic acid. The calibration curve was prepared from a standard consisting of sodium sulfide, sodium hydroxide, sodium salicylate, and ascorbic acid. The standard was titrated against a 0.1 M lead perchlorate solution to obtain the exact normality. Standards and samples were treated identically except standards were prepared by diluting in 25 percent SAOB. The electrodes were immersed in the sample, and the millivolt reading was recorded after it stabilized. The exact concentration of sulfide was determined from the standard curve (Orion IM, 1975c).

Round four samples were added directly to plastic bottles half filled with 50 percent SAOB in the field. The SAOB contained sodium hydroxide, disodium ethylenediaminetetraacetic acid (EDTA), and ascorbic acid. The calibration curve was prepared from a standard consisting of sodium sulfide and SAOB. The standard was titrated against 0.1 M lead perchlorate to find the exact normality of the standard. This solution was then serially diluted to prepare a standard curve. The samples and standards were treated identically. The electrodes were immersed in the sample, and millivolt readings were recorded. The exact concentration of sulfide was determined from the standard curve (Orion IM, 1976a).

Laboratory Analyses--

Boron--Boron was analyzed by the curcumin method. Samples were added to evaporating dishes made of boron-free glass. Curcumin reagent was added, and the dishes were placed in a water bath set at 55 ± 2^{0} C and evaporated to dryness. The contents of each dish were redissolved in 95 percent ethyl alcohol, filtered through Whatman 30 filter paper, and read at 540 nm on a spectrophotometer. The boron concentration was determined from a standard curve, which was prepared from standards serially diluted from a 100 mg/L boron stock solution (APHA, 1976).

Chemical oxygen demand--Samples were collected in plastic bottles containing sulfuric acid as a preservative and kept on ice until the analyses were completed. The dichromate reflux method was used for chemical oxygen demand (COD) determinations. The alternate procedure for dilute samples in which the potassium dichromate and ferrous ammonium sulfate are more dilute was used for low level COD samples (USEPA, 1974).

Chloride--Analyses for chlorides for the first two rounds were performed with a chloride electrode. During round two, a combination electrode was replaced with a chloride electrode and a double junction reference electrode. Due to problems with these electrodes, sample analyses of rounds three and four were completed by the mercuric nitrate titration method. Hach powder pillows (prepared indicator-acidifier reagent) were used as the indicator for round three, but the indicator-acidifier reagent was used for round four (APHA, 1971).

Prior to running analyses with a chloride electrode, standard curves were prepared from serially diluted standards of a 100 mg/L sodium chloride stock solution. Standards and samples were treated identically. The electrodes were immersed in samples with ionic strength adjuster (ISA) added. Samples were mixed at a constant rate on a magnetic stirrer until stable millivolt readings were observed. Using millivolt readings, unknown concentrations were determined from the calibration curve (Orion IM, 1976b).

Samples for titration were adjusted to a pH of 2.5 with nitric acid, and indicator-acidifier reagent was added to the sample, which was then titrated with 0.0141 N mercuric nitrate. If high chlorides were present, 0.141 N mercuric nitrate was used as the titrant. The samples were titrated to a light purple end point. Iron, which acts as an interference, was removed from the sample through flocculation with zinc sulfate solution and sodium hydroxide. The floc was allowed to settle and was filtered through a 0.45 micron filter. Analyses were performed on the filtrate (APHA, 1976).

Herbicides--Field samples were collected in hexane-rinsed, glass-stoppered bottles. Chlorinated phenoxy acid herbicides were extracted from the acidified water sample with diethyl ether. The ether layer was filtered through anhydrous sodium sulfate into hexane-rinsed bottles, 37 percent potassium hydroxide was added, and the sample was returned to the laboratory for analyses. Water was added to the sample and the ether removed by evaporation. Extraneous organic matter was removed by extracting the basic aqueous phase with diethyl ether. The aqueous phase was acidified to hydrolyze the esters to acids and the acids extracted with diethyl ether. Benzene was added and the solution evaporated to 0.5 mL in Kuderna-Danish evaporators.

The acids were esterified to methyl esters with 0.5 mL boron trifluoride in methanol. The benzene layer was shaken with neutral 5 percent sodium sulfate solution. The benzene extracts were further purified by passing through Florisil columns. Identification and quantification of the esters were made by gas-liquid chromatography and were corroborated through the use of two or more unlike columns (USEPA, 1974).

Metals (total)--Metal analyses were performed by atomic absorption spectrophotometry. Field samples were collected in plastic bottles and preserved with nitric acid to a pH 2. Two bottles were preserved for each sample. Round four samples were filtered at the well site through a 1 µm filter. All metals except for arsenic, selenium, and mercury were prepared by cautiously digesting with nitric acid and evaporating to dryness. Samples were refluxed with nitric acid and brought back to volume, then subjected to the standard conditions and instrumental parameters for the corresponding metals (USEPA, 1974; Martin, 1975; and Atomic Absorption Methods Manual, 1975).

Mercury was analyzed by the cold vapor technique. Concentrated sulfuric acid, concentrated nitric acid, 5 percent potassium permanganate, and potassium persulfate were added, and samples were heated 2 hours at 95° C in a water bath. Sodium chloride and hydroxylamine hydrochloride were added to samples. The mercury was vaporized by adding stannous sulfate (USEPA, 1974).

Arsenic and selenium were determined by atomic absorption, using a heated graphite atomizer and electrodeless discharge lamps. The samples were digested with nitric acid and hydrogen peroxide. Nickel nitrate was added to the digested samples prior to analysis (Martin, 1975).

Organic carbon (total and soluble)--Soluble organic carbon samples were filtered through a 0.45 micron Gelman filter and kept iced until prepared for analyses. Total organic carbon samples were not filtered. Purging and sealing of the ampules were done in the field. Ten mL glass ampules were prepared by adding 0.2 g potassium persulfate to 5 mL of sample and 0.5 mL of 3 percent phosphoric acid. Samples were then purged with oxygen. Phosphoric acid was prepared daily and added to the ampules just prior to sealing. Samples were prepared in triplicate. Carbon dioxide-free water was used for the blanks. Tests were performed in the laboratory to determine optimum length of time for purging and combusting the samples. The organic matter in the ampules was oxidized in a pressure vessel that was placed in an oven heated to 175° C for 16 hours.

After oxidation, the samples were analyzed with a carbon analyzer (USEPA, 1974, and Oceanography International IM, 1971).

Pesticides--Field samples were collected in hexane-rinsed, glass-stoppered bottles. Organochlorine pesticides were extracted from the water with an 85:15, hexane: methylene chloride solvent mixture in the field. The organic layer was filtered through anhydrous sodium sulfate into hexane-rinsed bottles and returned to the laboratory for analysis. The organochlorine pesticides analyzed were endrin, lindane, methoxychlor, and toxaphene. Extracted samples were concentrated in Kuderna-Danish evaporators in a hot water bath. The concentrated samples were purified, if necessary, by passing through Florisil columns. Identification and quantification of pesticides were made by gas-liquid chromatography and were corroborated through the use of two or more unlike columns (USEPA, 1971).

Solids (dissolved)--Samples were brought to room temperature, and well-mixed aliquots were passed through Reeve Angel, type 934 AH filters with gentle suction. One hundred mL was transferred quantitatively to pre-weighed evaporating dishes. Samples were evaporated to dryness at 100° C in a water bath and placed in an oven at 180° C for 1½ to 2 hours. Evaporating dishes were weighed again after cooling in a desiccator (USEPA, 1974).

Solids (suspended)--Samples were brought to room temperature and mixed thoroughly. Using gentle suction, 50 mL of sample was filtered through Reeve Angel, type 934 AH filters in 25 mL tared Gooch crucibles. The filtered samples were dried in an oven at 104° C for one to two hours. Crucibles and filters were desiccated until cool and reweighed (USEPA, 1974).

Solids (total)--Data for total solids were obtained by summing the dissolved and suspended solids values.

Solids (volatile suspended)--The solids retained on the filter from the suspended solids analysis were ignited at 550° C in a muffle furnace to determine volatile suspended solids (USEPA, 1974).

Sulfate sulfur--Round one was analyzed for sulfate with a lead specific ion electrode. Samples were diluted 1:1 with methanol. These were titrated with lead perchlorate until the millivolt readings fell within a range established by a blank curve. The exact sulfate concentration was extrapolated from a standard curve plotted on Grans plotting paper (Orion IM, 1975d).

Due to the inability to duplicate sulfate results using other methods, the remaining rounds of sulfates were analyzed turbidimetrically by the barium sulfate method. While the solution was being stirred, conditioning reagent and barium chloride crystals were added. After exactly one minute, the barium sulfate turbidity was read at 420 nm on a spectrophotometer, and the sulfate concentration was calculated from a standard curve prepared from serially diluted standards of a 1,000 mg/L sodium sulfate stock solution (APHA, 1976).

Methods for Analyses of Soils and Plants

Laboratory Analyses--

Since methods were similar for many of the parameters analyzed in soil and plant samples, these are discussed together in this section. In some instances, the method is only described for either soil or plants (such as pH of soil) or, if different, for each (such as pesticides in soil and in plants).

Cation exchange capacity--Air-dried soil samples (<2 mm particle size) and 1 N ammonium acetate were shaken for several minutes and allowed to stand overnight. Sample extracts were filtered through perforated Coors crucibles containing Reeve Angel glass fiber filters using gentle suction. Soil leaching was done with 1 N ammonium acetate, adding small amounts at a time so that leaching took no less than one hour. This was followed by leaching with 95 percent ethanol in small amounts until the leachate gave a negative test for ammonia with Nessler's reagent. The soil was air-dried and weighed.

Water was added, and ammonia was measured with an ammonia electrode by immersing into the sample and adding 10 N sodium hydroxide to raise the pH. Ammonia concentration was determined from a standard curve prepared from serially diluted standards of 1,000 mg/L ammonium chloride stock solution. No modifications were made for calcareous soils (Orion IM, 1975a; Busenberg, 1973; and Black, 1965).

Boron--Air-dried soil samples were refluxed with distilled water for 30 minutes. The soil-water suspension was separated by adding 1 N calcium chloride and centrifuging at 2,000 rpm for 10 minutes. The boron concentration of the supernatant was determined by the curcumin method. Plant samples were dry-ashed at 500° C for one hour in platinum crucibles, and the ash was dissolved in hydrochloric acid and water. Boron concentration was determined by the curcumin method (APHA, 1976, and Black, 1965).

Coliform in plants (total and fecal)--Plant samples were shaken by hand for 10 minutes in a sterile glass bottle containing sterile water and glass beads. Samples were then analyzed in triplicate, using 1 mL samples, by the same procedure used for analysis of total and fecal coliforms in water (Black, 1965).

Herbicides (plants)--Plant samples were mixed with 10 percent ethanolic sulfuric acid solution, petroleum ether, and ethyl ether. After centrifugation the extract was passed through anhydrous sodium sulfate. Sodium hydroxide (2 N) was added, followed by centrifugation. The ether fraction contained the esters and was cleaned with Florisil columns. The acids were liberated from the remaining aqueous solution by shaking with chloroform after acidification with sulfuric acid. After passing the chloroform through filter paper, it was evaporated to near dryness. Ether was added, and the remaining traces of chloroform were removed by evaporation. The extract was concentrated and transferred to a micro-KD evaporator. Benzene was added, and the extract was evaporated to 0.5 mL. Esterification was carried out with boron triflouride in methanol as described for herbicides in water. The benzene layer was passed through a micro-column of Florisil. Extracts were analyzed by gas chromatography (Yip, 1964).

Herbicides (soil)--Air-dried soil samples were mixed with water, sulfuric acid, and diethyl ether. After shaking for four hours, the extracts were filtered through anhydrous sodium sulfate. An aliquot of the ether extract was transferred to a separatory funnel and shaken with sodium hydroxide. The aqueous phase was transferred to another separatory funnel, the pH adjusted to 3, and extracted with ether. Mineral oil in hexane was added to the extract and evaporated carefully to 5 mL, employing a 50° C water bath and a Snyder column. The extract was further evaporated to 0.1 mL. The phenoxy acids were esterified using boron trifluoride in methanol, as described for herbicides in water (Woodham, 1971).

Metals (exchangeable and extractable)--Air-dried soil was pulverized by mortar and pestle to pass a 2 mm screen.

Aluminum was extracted with 1 N potassium chloride. The suspension was filtered immediately, and the solids were washed with 1 N potassium chloride

(Ellis, 1975). Aluminum was analyzed by atomic absorption.

The ions K, Mg, and Na were exchanged with 1 N ammonium acetate by shaking for five minutes. Extracts were filtered through Whatman No. 40 filter paper and analyzed by atomic absorption (Ellis, 1975).

The metals Fe, Zn, Mn, Cu, Ni, Pb, Cr, and Co were extracted from soils by shaking for two hours with triethanolamine, calcium chloride, and carboxymethylimino bis-ethylenenitrilo-tetraacetic acid (DTPA) (10 mL per 4 g soil), followed by filtering through Whatman No. 42 filter paper (Ellis, 1975). The metals were analyzed by atomic absorption.

Metals (total)--Samples were prepared by digesting soil in teflon beakers with hydrofluoric acid and evaporating the liquid to dryness. This was followed by digesting with a 3:1 hydrochloric: nitric acid mixture (aqua regia) for five minutes and then redissolving any residue in 1:1 hydrochloric acid. Samples were filtered and analyzed by atomic absorption spectrophotometry.

Total mercury analyses were prepared by digesting soils with aqua regia for two minutes in a 95° C water bath, followed by a 5 percent potassium permanganate digestion for 30 minutes. Sodium chloride, hydroxylamine hydrochloride, and distilled water were mixed with the sample and stannous sulfate was added to vaporize the mercury through the absorption cell. Plant samples were also analyzed by this procedure (USEPA, 1974).

Total arsenic and selenium analyses were prepared by refluxing the soil samples two times with nitric acid, followed by digestion with hydrogen peroxide and nitric acid. Nickel nitrate was added to the digested samples prior to analyses by atomic absorption, using the heated graphite atomizer and electrodeless discharge lamps. Plant samples were prepared in a similar manner.

Nitrogen (inorganic)--Because ammonia, nitrate, and nitrite nitrogen readily change form in soil, these parameters were summed to obtain inorganic nitrogen values. Ammonia, nitrate, and nitrite nitrogen were determined by the following methods:

Ammonia nitrogen was determined after extracting air-dried soil with 2 N potassium chloride by shaking on a rotary shaker for two hours. Samples were allowed to sit for 30 minutes before being analyzed for ammonia with an ammonia electrode. The probe was immersed in the sample, followed by the addition of sodium hydroxide to raise the pH. Ammonia concentration was determined from a standard curve prepared from serially diluted standards of a 1,000 mg/L ammonium chloride stock solution. A 1-gram plant sample was analyzed for ammonia nitrogen following this same procedure (Orion, IM, 1975a, and Black, 1965).

For the nitrate and nitrite nitrogen determination, potassium chloride (2 N) was used to extract the ammonia, nitrate, and nitrite from the air-dried soil by shaking together for one hour. The suspension was filtered through Whatman No. 4 filter paper. The pH was adjusted between 11 and 14 with 10 N sodium hydroxide. At least half the volume of the filtrate was evaporated by boiling, to drive off all ammonia nitrogen. After cooling and adjusting the filtrate to the original volume, concentrated sulfuric acid and Devarda's alloy were added. Samples were placed in a 70° C water bath for two hours for reduction of nitrate and nitrite to ammonia. Ammonia concentrations of the solutions were measured with an ammonia electrode after addition of sodium hydroxide. Ammonia concentration was determined from a standard curve prepared from serially diluted standards of a 1,000 mg/L ammonium chloride stock solution. Plant samples were analyzed for nitrate-nitrite nitrogen following this same procedure (Orion IM, 1975b; Orion IM, 1976c; and Black, 1965).

Nitrogen (organic)--Air-dried soil was digested with concentrated sulfuric acid, potassium sulfate, cupric sulfate, and selenium. The solutions were evaporated for 30 minutes past the disappearance of sulfurous acid fumes. Samples were diluted, neutralized with sodium hydroxide, and analyzed with an ammonia electrode. Ammonia concentration was determined from a standard curve prepared from serially diluted standards of a 1,000 mg/L ammonium chloride stock solution. Plant samples were digested in the presence of concentrated sulfuric acid and analyzed for total organic nitrogen following this same procedure (Orion IM, 1975a; Bremner, 1972; and Black, 1965).

Pesticides (plants)--Plant samples mixed with Celite were extracted with acetonitrile and filtered with vacuum. An aliquot of filtrate was shaken with petroleum ether. Water saturated with sodium chloride was mixed with the ether. The aqueous phase was discarded, and the ether phase was washed twice with water. The ether phase was dried with anhydrous sodium sulfate. Samples were analyzed by gas chromatography (Mills, 1963).

Pesticides (soil)--Soil samples were air-dried, mixed with Celite, and Soxhlet extracted for 12 hours with hexane: acetone (41:59 v/v). The extracts were then shaken in a separatory funnel with a saturated sodium chloride solution and extracted with hexane. The extracts were washed twice with a saturated sodium chloride solution. The hexane phase was dried with anhydrous sodium sulfate. Unless further purification was necessary, the samples were ready for gas chromatographic analyses (Williams, 1968).

pH--The soil was air-dried and pulverized by mortar and pestle before samples were analyzed. Twenty-five mL of distilled water per gram of soil was added and the mixture stirred. The hydrogen ion concentration (pH) was measured while the sample was mixing (Black, 1965).

Phosphorus (available)--Samples of air-dried soil were extracted with 0.03 N ammonium fluoride and 0.025 N hydrochloric acid by shaking for one minute. The extract was filtered through Whatman No. 42 filter paper and the pH adjusted to 7.0 ± 0.2 with sodium hydroxide. Color reagent (mixture of antimony potassium tartrate, ammonium molybdate, and ascorbic acid) was added, and the absorbance was read at 640 nm with a spectrophotometer (APHA, 1976, and Black, 1965).

Phosphorus (total)--Air-dried soil samples were digested with 6 percent perchloric acid in a flask. Samples were boiled until the dark color due to organic matter disappeared. An aliquot was adjusted to pH 7.0 ± 0.2 with sodium hydroxide, followed by the addition of color reagent. After color development, absorbance was measured on a spectrophotometer at 640 nm. Plant samples were digested in the presence of concentrated sulfuric acid and analyzed for total phosphorus following this same procedure (APHA, 1976, and Black, 1965).

Sulfur (total)--The presence of large amounts of sulfur in Roswell soils made it very difficult to separate sulfate sulfur and organic sulfur; thus the two were combined to obtain total sulfur values.

For the determination of sulfate sulfur, monobasic calcium phosphate was added to air-dried soil samples and shaken for 12 hours, followed by filtering through a Gooch crucible fitted with a glass fiber filter. An aliquot of filtrate, gum acacia solution, and hydrochloric acid was mixed with barium chloride crystals. Absorbance was measured at 420 nm on a spectrophotometer. The concentration of sulfur in the samples was determined from a standard curve prepared from serially diluted standards of a stock sulfate solution. This procedure was also used to analyze sulfate sulfur in plant samples (Black, 1965).

The residue in the Gooch crucible from the sulfate sulfur determination was used for organic sulfur analyses. After drying at 103° C, sodium bicarbonate was mixed with the soil and added uniformly as a surface layer. After ignition at 500° C for three hours the sample was extracted and analyzed as described for sulfate sulfur (Black, 1965).

Methodology Problems and Modifications

As indicated previously, certain difficulties in analyses were experienced in using the standard methods. The following sections discuss the problems encountered in the water, soil, and plant analyses and indicate the modifications that were employed in an attempt to obtain measurements of the parameters involved in the study. Table 7 summarized the modifications for field methods for each of the sampling rounds during the study.

The problems and modifications are mentioned for two reasons. First, for time-critical parameters, it may be the explanation for missing data for certain samples. If the method was known to be faulty, the data were deleted from the data tabulation shown in Appendix B. Second, certain analytical procedures were modified to obtain accurate results for the types of samples encountered in this study. These modifications are reported for the benefit of future investigators for similar type studies. Also, it was deemed valuable to report those cases when certain new analytical tools did not conform to the manufacturer's claims.

Water Analyses--

Calcium--Initial review of calcium data indicated low values were being generated. Spiked samples indicated low recoveries. Therefore, all samples were repeated and were run by the method of standard addition. Excellent recoveries were obtained; therefore, all calcium data are valid.

Chemical oxygen demand--Results from some of the early field samples stimulated questions concerning the procedure being used. Extensive spiking and duplication of samples showed no methodology problems and no reason for the anomalous data.

Chloride--The initial problem was a faulty electrode. Later problems involved matrix interferences. The probe method was replaced by mercuric nitrate titrations as listed in the EPA methods manual (USEPA, 1974).

Metals--Data from several metals appeared anomalous at some time during the analyses. A malfunctioning atomic absorption (AA) was initially a problem. Failures included several faulty hollow cathode lamps, a faulty printed circuit board in the photomultiplier, an out-of-tolerance nebulizer, and numerous graphite rods (cuvettes) that had been manufactured without meeting specifications. Analyses in question were repeated, using an operational instrument. All metal analyses reported are considered valid data.

Nitrate nitrogen--The nitrate probe was used according to the manufacturer's directions with success for some samples, but problems were encountered with other samples. Discussions with the manufacturer resulted in new filling solutions for the probe and different ionic strength adjuster solutions to aid in reducing interferences. Some faulty probes were also discovered during the analyses. Although the probe method was abandoned during round two sampling, nitrate values obtained by the probe were comparable to Cd reduction method values, and data were thus considered valid.

Organic nitrogen--The EPA method was modified initially by using the ammonia probe instead of distilling the ammonia and titrating. It was discovered later that the temperature of the solutions measured with the electrode varied markedly, depending on the amount of acid in the solutions. This temperature variation affected the probe adversely; thus, it was found necessary to partially neutralize samples to about pH 5, cool to room temperature, then add the remainder of the base and measure the ammonia with the probe. Several items concealed this problem initially. Three electrode failures were experienced, and thus questionable data were attributed to this. It was also discovered that mercuric ions in the digesting reagent were not releasing the ammonium during analyses.

Sulfate sulfur--The sulfate (lead) probe was used according to the manufacturer's directions with little success at the sampling sites, although initial tests proved the method satisfactory. Discussions with the manufacturer resulted in numerous changes in the solutions used during analyses. The probe was later found to be faulty as well. The probe was abandoned, and only turbidimetric measurements were used for remaining samples.

Soil and Plant Analyses--

Inorganic nitrogen--Nitrate + nitrite nitrogen was determined initially according to the ASOA method, with the exception that steam distillation of ammonia was replaced by the use of the ammonia probe. Spiked samples indicated that reduction of nitrate and nitrite was limited and that the method was underestimating the concentrations of nitrate and nitrite nitrogen. After much experimentation, it was discovered that the Devarda alloy would not reduce NO_3 and NO_2 to NH_4 without the addition of a proton donor. Satisfactory results were obtained by adding small amounts (<1 mL) of concentrated H_2SO_4.

Organic nitrogen (total)--The method as described by Bremner and Tabatabai (1972) was followed initially. The temperature interference described for the organic nitrogen procedure for water samples was initially a problem for soil and plant samples. Partial neutralization followed by cooling solved the difficulty of obtaining accurate results.

DATA EVALUATION PLAN

General background data about the site including geology, hydrogeology, soils, climate, and other relevant information have previously been presented.

Data collected at the field site from wells, effluent samples, soils, and crops were transmitted to the laboratory for collation and computer tabulation. Additional analytical procedures at the laboratory provided data on many parameters, which were integrated with field data. Appendix B provides complete data tables for all parameters that had reliable, internally consistent results. In some instances columns of data were combined, such as ammonium and nitrate-nitrite nitrogen, if analytical procedures indicated that individual parameters might overlap.

In the Results and Discussion section the critical resource values of water, soils, and crops are compared for the test and control sites.

The evaluation of the results of water analyses is presented in three parts: effluent, surface runoff, and groundwater. In each part the results are discussed in relation to such site characteristics as hydrology, renovation performance of the soil, or quality of the groundwater. In addition, some projections are attempted for long-term loadings of critical parameters contained in the wastewater. The groundwater data that differentiated between control and test sites were essentially the following: COD, Cl, NO_3-N, TDS, B, K, Na, SO_4, P, heavy metals, and pesticides.

For soils the results that merited discussion include P, N, and selected heavy metals. Although values were obtained for many other parameters, the differences between control and test sites were generally within the range of variability expected for any one soil site. The soil data that differentiated between control and test sites as a function of depth below surface were the following: Cr, Cu, Zn, organic N, and total P. For the corn crop the parameters for which the data differentiated the control and test sites were the following: organic N, P, Mg, Na, and Zn.

Finally, the possible adverse health effects associated with viruses and fecal and total coliform bacteria were investigated in water and crop samples. Discussion of the methods used and the results obtained for these health-effects parameters follow in the sections on water and crops.

SECTION 7

RESULTS AND DISCUSSION

Samples collected in the field were identified by a code number that was used on all data tables and graphs as well as in the narrative sections where individual sample results are discussed. Water samples had a six-digit number and were coded as follows: The first digit (1) referred to the Roswell site; the second digit indicated whether sample was from a control (1) or test (2) site; the third and fourth digits indicated the sample number--01 to 40 were taken from wells, 41 to 43 were taken from lysimeters, 45 were surface runoff samples which were collected twice after 2.5 cm (1.0 in) of rainfall on September 9, 1976, and April 14, 1977, 46 and 47 were irrigation and effluent water samples. The fifth digit indicated a single or multiple completion well. A zero indicated a single well; and for multiple wells 1 was for shallow, 2 for mid-depth, and 3 for deep wells. The sixth digit indicated the sampling round: 1, first; 2, second; 3, third; and 4, fourth. Dates for sampling rounds are given in the tables.

Soil samples were similarly coded except that only five digits were used. The first and second digits were the same as for water samples. The third digit indicated the sub-area of the control or test site (Figure 9). The fourth digit indicated the sampling round. The fifth digit indicated the relative sample depth: 1 was 0 to 2 cm, 2 was 2 to 4 cm, 3 was 9 to 11 cm, 4 was 29 to 31 cm, 5 was 95 to 105 cm, and 6 was 295 to 305 cm.

Plant samples were identified with four-digit numbers and followed the same format as soils except that the fifth digit was not used.

WATER

Effluent Constituents

The Roswell Wastewater Treatment Plant produced an effluent for irrigation that is typical of a secondary effluent insofar as a majority of the chemical constituents is concerned. Laboratory analyses of the effluent were run in June and October of 1976 and in January and April of 1977, representing the four seasons of the year. The results are summarized in Table 8 for effluent sample numbers 124601 through 124604 (sample numbers 124605 and 124606 are effluent samples taken during the fourth sampling trip for partial analysis) and irrigation well sample numbers 114601, 114604, and 114701.

Five-day biochemical oxygen demand (BOD_5) was typically in the range of 10 to 20 mg/L with suspended solids (SS) of 20 to 30 mg/L. The October,

TABLE 8. SUMMARY OF CONSTITUENTS DEFINING DIFFERENCES IN APPLIED WATERS

Constituent (mg/L, unless noted)	Applied Waters			
	Test Site (Final Effluent)		Control Site (Irrigation Wells)	
	Range	Mean	Range	Mean
Dissolved Oxygen	<0.1-6.1	2.0	7.3-7.7	7.5
Alkalinity as $CaCO_3$	316-336	323	168-196	183
Dissolved Solids	2008-2504	2195	2374-3027	2700
Suspended Solids	18-74[a]	41.7	28[b]	28[b]
Total Solids	2041-2522	2237	2727[b]	2727[b]
Biochemical Oxygen Demand	6-122[a]	42	<1-2	1
Chemical Oxygen Demand	135-206	172	19-44	29
Dissolved Organic Carbon	13.9-57.9	28	8.4[b]	8.4[b]
Soluble Organic Nitrogen	<0.1-36	11	0.5-1.6	1.0
Ammonium Nitrogen	16.8-25.6	23.0	<0.1-0.1	<0.1
Nitrate Nitrogen	0.10-3.7	1.6	0.5-2.3	1.6
Total Phosphorus	5.2-9.5	8.0	0.01[b]	0.01[b]
Soluble Phosphorus	4.8-8.0	6.8	0.01[b]	0.01[b]
Soluble Orthophosphate Phosphorus	3.8-7.8	6.5	0.01[b]	0.01[b]
Sulfate Sulfur	518-917	660	713[b]	713[b]
Chloride	545-820	681	710-933	844
Boron	0.133-0.208	0.337	0.235-0.455	0.179
Calcium	124-262	192	122-344	226
Iron	<0.2-1.8	0.64	<0.2-0.6	0.43
Magnesium	59-86	67	53-92	74
Potassium	13.7-16.8	14.7	2.1-6.2	4.8
Sodium	350-559	466	380-424	398
Zinc	0.01-0.09	0.05	<0.01-0.07	0.03
Lindane, ng/L	49.2-1250	588	1.3-72	26
2,4-D, ng/L	<1.2-64	29	0.6-18.4	7.6
2,4,5 TP Silvex, ng/L	<0.2-70.4	28.1	0.2-5.8	2.0

[a] Treatment plant overloaded during second sampling round.

[b] Results from one sample only.

1976, effluent sample contained high BOD_5 and SS concentrations of 122 and 74 mg/L, respectively. The treatment plant was overloaded hydraulically during this sampling round.

The chemical oxygen demand (COD) concentration of the effluent was uniformly high throughout the testing period. Concentrations ranged from 135 to 206 mg/L, which is two to three times the normal COD concentration of secondary effluent. The relatively normal BOD_5 concentrations contrasted with the relatively high COD concentrations suggested the presence of 50 to 100 mg/L of COD concentration attributable to slowly biodegradable organic materials. A possible source of these materials could be the packing plant wastewater. Although the packing plant wastewater was reportedly pretreated, this type of wastewater typically contains relatively high concentrations of proteinaceous organics that are slow to biodegrade.

The ammonium nitrogen concentration was in the normal secondary effluent range of 15 to 25 mg/L. Nitrate nitrogen concentrations reflected the partial nitrifying condition that existed during the warmer summer and fall periods in Roswell. Organic nitrogen would generally be at a minimal concentration in such an effluent, but the analyses showed high soluble organic nitrogen concentrations of 15 to 36 mg/L. This was consistent with the observations made earlier concerning the presence of packing plant wastewater and the possible contributions of relatively high concentrations of nitrogen and proteinaceous organics.

Phosphorus concentrations, which were in the range of 5 to 10 mg/L, were typical of secondary effluents. The high sulfate sulfur concentrations reflected the natural geochemistry of the water supply aquifer that has common anhydrite deposits. The dissolved solids concentration of the effluent was consistent with the relatively high dissolved solids concentration of the Roswell potable water supply. The metallic ions, with the exception of the geochemical contributions of very soluble sodium and mildly soluble calcium and magnesium, were present in expectedly low concentrations. The chlorinated hydrocarbon lindane was discernible in the effluent at concentrations higher than were found in other water samples including the potable water supply and area groundwater supplies.

Overall observations that can be made concerning the Roswell Wastewater Treatment Plant effluent are: (1) most parameters were reasonably typical of secondary effluent except for the COD and soluble organic nitrogen concentrations, which were unusually high, possibly reflecting wastewater input from a packing house; (2) high sulfate sulfur concentrations reflected the naturally occurring anhydrite deposits that exist in the hydrogeologic system from which Roswell derives potable water; and (3) lindane, an insecticide that has an applicable National Interim Primary Drinking Water Regulation maximum contaminant level (MCL) of 4,000 ng/L, was identified at above background levels and at a maximum measured concentration of 1,250 ng/L.

Surface Runoff

Surface runoff samples were collected at the southeast corner of the test site in September, 1976, and April, 1977, and are designated in Appendix

B as sample numbers 124501 and 124502, respectively. A control site surface runoff sample was collected near monitoring wells 11050 and 11060 on control site B and is designated 114502 in Table 9.

TABLE 9. WATER QUALITY OF SURFACE RUNOFF

	Concentration in mg/L		
	Control	Test	
Parameter	114502	124501	124502
Chemical Oxygen Demand	79	246	73
Total Nitrogen	6.9		9.5
Dissolved Solids	129		357
Suspended Solids	2223		595

The occurrence of natural precipitation events plus the schedule for irrigation application, agricultural events, and time of sampling are depicted in Figure 6. The surface runoff from which the samples were taken was induced by natural precipitation. Samples were collected and preserved by a representative of the New Mexico Environmental Improvement Agency and shipped to the contractor's laboratory for analysis.

Ammonia, nitrate, and organic nitrogen analyses were available for the April, 1977, runoff sampling at both the control and test sites. Total nitrogen was 6.9 mg/L from the control site and 9.5 mg/L from the test site. Although these concentrations were fairly comparable and only this sparse data existed, there was a suggestion that the test site runoff reflected the improved nitrogen nutrient status of the test site soil. Further information about the control and test site soils is discussed in a subsequent section of this report. The nitrogen concentrations observed in the runoff samples were within the normal range for runoff from agricultural or other productive soils.

Phosphorus data existed for only the April, 1977, test site runoff sample. The soluble orthophosphate phosphorus concentration of 2.7 mg/L was consistent with runoff from reasonably productive soils. The presence of suspended solids in the runoff sample could account for a total phosphorus concentration higher than the soluble orthophosphate phosphorus concentration. Soil or suspended solids transport during precipitation events is a primary mechanism for phosphorus runoff from agricultural land.

The dissolved solids concentration in the April, 1977, control site runoff was 129 mg/L, which is less than the 357 mg/L occurring in the test site runoff. This likely reflected the higher concentration of dissolved solids associated with the topsoil at the test site as a result of the irrigation practices and the ensuing evapotranspiration processes. The dissolved solids concentrations in both runoff samples were far less, however, than those of any groundwater or effluent source near Roswell. These data substantiated that the runoff samples were from recent precipitation.

The suspended solids concentrations of the April, 1977, runoff samples for both control and test sites are also presented in Appendix B. These relatively large concentrations confirm that topsoil transport was occurring, with the control site producing more sediment at 2,223 mg/L than the test site at 595 mg/L.

Overall observations from the surface runoff monitoring are: (1) sediment content in all runoff samples tended to control the results from many of the analyses; (2) soluble nitrogen concentrations were within a normal range for agricultural runoff, with the test site possibly indicating its enhanced soil nitrogen concentration; and (3) phosphorus concentrations were within the normal range for agricultural runoff when soil transport is involved.

The metal concentrations in the runoff samples were total metals; that is, the samples were not filtered and were acid digested before analyses.

Groundwater

It is necessary to review here some of the factors affecting groundwater quality around and on the test site before individual groundwater parameters can be meaningfully discussed. Groundwater in the alluvium aquifer, which potentially extends from the ground surface to a depth of approximately 9 m (30 ft), moved in a southeast, east, or northeast direction across the test site. Average rate of movement was 1.8 to 2.4 m (6 to 8 ft) per day. Figure 5 shows the groundwater contours and direction of groundwater movement observed on the test site. Depth from ground surface to the top of the saturated zone was generally 2 to 3 m (7 to 10 ft) (Table 3). Recharge to the alluvium aquifer has been analyzed as almost completely supplied from irrigation practices both on and around the test site. Estimated average yearly recharge to the alluvium aquifer was estimated at 20 cm (7.9 in) per year from a total yearly irrigation application of 80 cm (32 in) per year. While irrigation on the test site was uniformly practiced with effluent from the Roswell Wastewater Treatment Plant, the practices on the surrounding lands were more varied. Figure 7 illustrates the overall effluent and sludge application area immediately west and extending somewhat north of the test site.

A general location map of the Roswell area and an enlarged map show the control site locations (Figures 2 and 3). Note that the westernmost control site, Site A, was well removed from the effluent irrigation areas.

In addition to irrigation with effluent, irrigation with groundwater from the shallow aquifer underlying the alluvium was practiced throughout the

Roswell area. The open areas on Figure 7 between effluent irrigation areas were locations where irrigation with groundwater was practiced.

Groundwater monitoring wells plus a lysimeter were installed on the test site at locations shown on Figure 12. Additional groundwater monitoring wells were installed on the control sites as shown on Figure 3. Groundwater samples were taken from these wells at four times during the year, June and October of 1976 and January and April of 1977. The groundwater samples were analyzed for a number of quality parameters, which are recorded in Appendix B. In addition to the groundwater monitoring samples and effluent and surface runoff samples discussed previously, sample numbers 116002 to 116004 were potable water samples taken from the Roswell municipal supply, and sample numbers 114701, 114601, and 114604 were composite groundwater irrigation well samples from two upstream and eight downstream wells, respectively.

Roswell potable water is primarily obtained from the artesian San Andres formation. Although the water quality from this aquifer is highly variable at different locations, lower dissolved solids, chloride, and sulfate concentrations are available locally from the San Andres formation than from either of the alluvial aquifers.

Groundwater irrigation wells tap the shallow aquifer. The dissolved solids, chloride, and sulfate concentrations in this aquifer are intermediate to respective concentrations in the artesian and the irrigated alluvium aquifers as illustrated in the following comparison.

	Concentrations in mg/L		
Aquifer	Dissolved Solids	Chloride	Sulfate
San Andres, artesian	1400	300	500
Shallow	2500	800	700
Irrigated alluvium	6000	2400	1800

All alluvium well samples in the test and control site areas were affected by tributary irrigation. The concentrations of dissolved solids, chloride, and sulfate in the alluvium water samples were independent of the source of the irrigation water. The irrigation well water, the source of which is the shallow aquifer, and the irrigation treatment plant effluent have comparable respective concentrations of dissolved solids, chloride, and sulfate. Other typical quality parameters observed in the groundwater irrigation water from samples 114701, 114601, and 114604 are listed in Table 10.

Table 11 depicts sample mean concentrations of various parameters measured in the water used for irrigation on the test site (effluent) and control site (shallow aquifer). A statistical analysis of the sample data using the method of pooled variances was utilized to evaluate whether a significant difference at the 0.05 level existed between the means of the

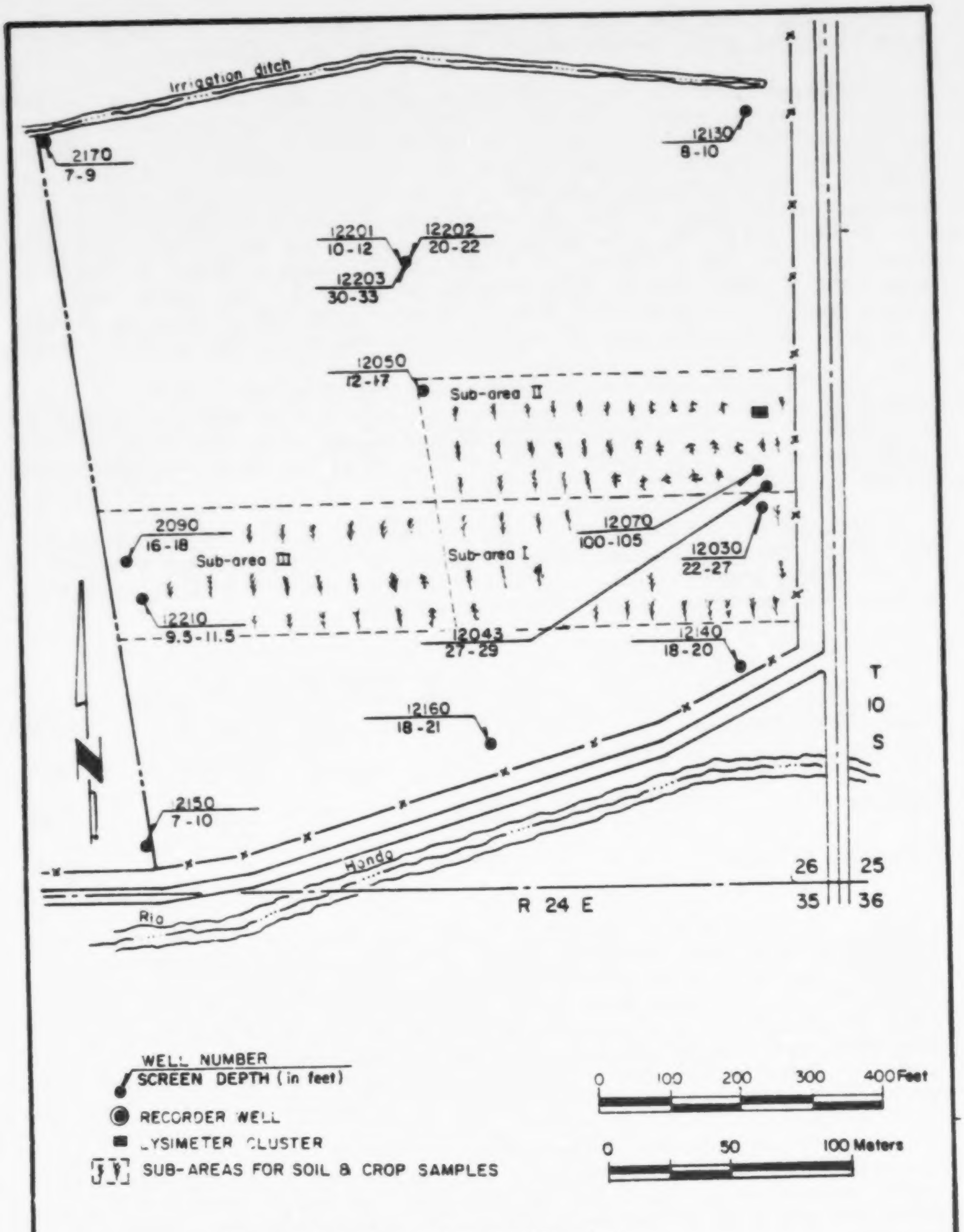


Figure 12. Irrigation study site.

TABLE 10. TYPICAL YEARLY AVERAGE QUALITY PARAMETERS FOR IRRIGATION GROUNDWATER

	Concentration, Units of mg/L Unless Otherwise Noted		
Parameter	114701, 6/76	114601, 6/76	114604, 4/77
Dissolved Solids	2374	3027	2699
Chemical Oxygen Demand	44	24	19
Chloride	710	889	933
Soluble Organic Nitrogen	1.0	1.6	0.5
Nitrate Nitrogen	2.3	1.9	0.5
Ammonium Nitrogen	<0.1	<0.1	0.1
Soluble Phosphorus	1.90	0.24	0.01
Soluble Orthophosphate Phosphorus	0.02	0.10	0.01
Sulfate	--	--	713
Boron, μg/L	208	195	133
Potassium	2.1	6.2	6.0
Sodium	380	424	391
Iron	0.6	0.6	<0.2
Manganese	0.02	<0.01	<0.05
Selenium, μg/L	--	--	<10
Zinc, μg/L	70	<10	<20
Lindane, ng/L	4.1	72	1.3

TABLE 11. MEAN CONCENTRATIONS OF PARAMETERS FOR IRRIGATION WATERS USED ON TEST (EFFLUENT) AND CONTROL (SHALLOW AQUIFER) SITES

Parameter	Means (mg/L unless noted) Control	Means (mg/L unless noted) Test
Dissolved Oxygen	7.7	2.1
pH	7.5	7.6
Conductivity	3599	3170
Total Alkalinity	176	323[a]
Dissolved Solids	2863	2194[a]
Biochemical Oxygen Demand	1.3	43
Chemical Oxygen Demand	22	172[a]
Chloride	911	681
Sulfide-S	0.1[b]	0.3
Total Coliform	4359	TNTC[c]
Fecal Coliform	3	TNTC
Total Organic C	--	60.5
Dissolved Organic C	8.4	27.9
Total Organic N	--	41.3
Soluble Organic N	1.1	11.0
Ammonium-N	0.1	23.3[a]
Nitrate-N	1.2	1.6
Total Phosphorus	0.01	7.95[a]
Soluble Phosphorus	0.12	6.85[a]
Soluble Orthophosphate	0.05	6.47[a]
Sulfate	713	659
Aluminum	0.5	0.5
Arsenic (μg/L)	20[b]	20[b]
Boron (μg/L)	164	338
Cadmium (μg/L)	20[b]	20[b]
Calcium	279	192
Cobalt (μg/L)	50[b]	50[b]
Chromium (μg/L)	10	22
Copper (μg/L)	50	71
Iron	0.35	0.64
Lead (μg/L)	100[b]	100[b]
Magnesium	84	67
Manganese	0.05[b]	0.05[b]
Mercury (μg/L)	0.50[b]	0.62
Nickel (μg/L)	50[b]	50[b]
Potassium	6.1	14.7[a]
Sodium	408	466
Zinc (μg/L)	50[b]	76
Selenium (μg/L)	10[b]	10[b]

[a] Test and control sites are significantly different at the 0.05 level.

[b] Concentrations below detection limit indicated.

[c] At least one sample analyzed too numerous to count.

test site irrigation water and the control site irrigation water. The results of the statistical analysis reveal that at the 0.05 level of significance, higher mean values for total alkalinity, chemical oxygen demand, ammonia, total phosphorus, soluble phosphorus, soluble orthophosphate, and potassium existed in the irrigation effluent at the test site than in the irrigation water at the control site. Mean dissolved solids concentration was the only parameter identified as being significantly higher in the control site irrigation water than in the test site irrigation water. For parameters with mean concentrations at or below detection limits, and for coliform data with samples yielding too numerous to count (TNTC), no analysis could be performed. For the remaining parameters, there was no significant difference at the 0.05 level.

The same statistical method was used to make various comparisons between constituent concentrations in the groundwater at the control site and the test site. The first analysis was a comparison between the mean concentration of various parameters for groundwater in the control site wells (11060 and 11050) versus all test site wells. The deep well (12070) on the test site was excluded from the analysis. Table 12 contains the sample mean concentrations calculated for all rounds and the statistical analysis results. Total alkalinity and nitrate were the only parameters found to have greater mean concentrations in the groundwater at the test site than in the groundwater at the control site at the 0.05 level of significance. In contrast, pH, chloride, ammonia, sodium, and selenium are parameters where a significant difference at the 0.05 level existed with the sample mean concentrations greater at the control site than at the test site. For each of the remaining variables shown in Table 12, no significant difference at the 0.05 level was found to exist between the control and test site groundwaters. Tables 13 through 16 present the same comparison for the groundwaters on an individual sample round basis. For round one (June, 1976), Table 13 shows only pH to vary significantly at the 0.05 level between the control site and the test site, with the control site yielding the largest value. For all other parameters in Table 13, no significant difference existed for round one. Table 14 shows aluminum was the only parameter during round two (October, 1976) with a significant difference at the 0.05 level, and the concentration was greatest for the control site. For round three (January, 1977), Table 15 shows alkalinity, with concentrations greater on the test site, to be the only parameter with a significant difference at the 0.05 level. Finally, for round four (April, 1977), selenium and pH showed significant differences with greater concentrations existing in the groundwater at the control site (Table 16).

It is important to reiterate that for those parameters with sample means at or below detection limits and for coliform data yielding TNTC values, a statistical comparison is not possible. However, some general trends can be observed. With few exceptions, when a parameter mean concentration was below detection limits for the control site, it was also at or below detection limits for the test site. The only exception to the overall comparison (Table 12) was for arsenic, with the control site wells yielding an average concentration of 25.8 μg/L compared to the test site wells with an average concentration below the detection limit of 20 μg/L.

TABLE 12. MEAN CONCENTRATIONS OF PARAMETERS IN TEST AND CONTROL SITE GROUNDWATERS (DEPTH LESS THAN 30 METERS)

Parameter	Means (mg/L unless noted) Control	Test
Dissolved Oxygen	1.6	2.0
pH	7.3	7.1[a]
Conductivity	9260	7806
Total Alkalinity	220	325[a]
Dissolved Solids	6392	6096
Biochemical Oxygen Demand	1[b]	1[b]
Chemical Oxygen Demand	45	51
Chloride	2514	1786[a]
Sulfide-S	0.1[b]	0.1[b]
Total Coliform	TNTC[c]	TNTC
Fecal Coliform	2	30
Total Organic C	--	--
Dissolved Organic C	11.6	14.0
Total Organic N	--	--
Soluble Organic N	0.8	0.7
Ammonium-N	0.4	0.2[a]
Nitrate-N	1.0	9.8[a]
Total Phosphorus	--	--
Soluble Phosphorus	0.55	0.38
Soluble Orthophosphate	0.11	0.14
Sulfate	1979	1871
Aluminum	1.1	1.2
Arsenic (μg/L)	26	20[b]
Boron (μg/L)	245	375
Cadmium (μg/L)	20[b]	20[b]
Calcium	437	525
Cobalt (μg/L)	50[b]	50[b]
Chromium (μg/L)	20[b]	20[b]
Copper (μg/L)	53	63
Iron	7.5	51
Lead (μg/L)	100[b]	100[b]
Magnesium	150	166
Manganese	0.15	0.11
Mercury (μg/L)	0.5[b]	0.5[b]
Nickel (μg/L)	63	65
Potassium	11.9	9.7
Sodium	1653	1097[a]
Zinc (μg/L)	86	127
Selenium (μg/L)	52	30[a]

[a] Test and control sites are significantly different at the 0.05 level.

[b] Concentrations below detection limit indicated.

[c] At least one sample analyzed too numerous to count.

TABLE 13. MEAN CONCENTRATIONS OF PARAMETERS IN TEST AND CONTROL SITE GROUNDWATERS SAMPLED JUNE, 1976 (DEPTH LESS THAN 30 METERS)

Parameter	Means (mg/L unless noted)	
	Control	Test
Dissolved Oxygen	1.1	2.1
pH	7.2	6.9[a]
Conductivity	7910	7508
Total Alkalinity	246	369
Dissolved Solids	6073	6335
Biochemical Oxygen Demand	1[b]	1[b]
Chemical Oxygen Demand	36	79
Chloride	2070	1717
Sulfide-S	--	--
Total Coliform	TNTC[c]	TNTC
Fecal Coliform	0	114
Total Organic C	--	--
Dissolved Organic C	--	19.3
Total Organic N	--	--
Soluble Organic N	1.7	1.5
Ammonium-N	0.1[b]	0.1[b]
Nitrate-N	1.5	13.3
Total Phosphorus	--	--
Soluble Phosphorus	2.05	1.44
Soluble Orthophosphate	0.34	0.49
Sulfate	--	--
Aluminum	1.6	2.2
Arsenic (μg/L)	--	--
Boron (μg/L)	230	215
Cadmium (μg/L)	20[b]	20[b]
Calcium	288	423
Cobalt (μg/L)	50[b]	50[b]
Chromium (μg/L)	20[b]	20[b]
Copper (μg/L)	170	205
Iron	2.0	1.7
Lead (μg/L)	100[b]	100[b]
Magnesium	115	89
Manganese	0.05[b]	0.16
Mercury (μg/L)	0.5[b]	0.5[b]
Nickel (μg/L)	50.0[b]	50.0[b]
Potassium	8.2	6.7
Sodium	1443	967
Zinc (μg/L)	50[b]	141
Selenium (μg/L)	--	--

[a] Test and control sites are significantly different at the 0.05 level.

[b] Concentrations below detection limit indicated.

[c] At least one sample analyzed too numerous to count.

TABLE 14. MEAN CONCENTRATIONS OF PARAMETERS IN TEST AND CONTROL SITE GROUNDWATERS SAMPLED OCTOBER, 1976 (DEPTH LESS THAN 30 METERS)

Parameter	Means (mg/L unless noted) Control	Test
Dissolved Oxygen	1.9	1.6
pH	7.4	7.1
Conductivity	10,535	8494
Total Alkalinity	200	327
Dissolved Solids	6788	6003
Biochemical Oxygen Demand	1[b]	1[b]
Chemical Oxygen Demand	70	60
Chloride	2452	1632
Sulfide-S	--	--
Total Coliform	0	13
Fecal Coliform	0	0
Total Organic C	--	--
Dissolved Organic C	7.7	4.9
Total Organic N	--	--
Soluble Organic N	0.2	0.2
Ammonium-N	0.5	0.1[b]
Nitrate-N	2.5	13.3
Total Phosphorus	--	--
Soluble Phosphorus	0.04	0.04
Soluble Orthophosphate	0.04	0.04
Sulfate	2016	2035
Aluminum	1.8	0.6[a]
Arsenic (μg/L)	37	20[b]
Boron (μg/L)	293	624
Cadmium (μg/L)	20[b]	20[b]
Calcium	505	646
Cobalt (μg/L)	50[b]	50[b]
Chromium (μg/L)	24	20[b]
Copper (μg/L)	20[b]	22
Iron	27	187
Lead (μg/L)	100[b]	100[b]
Magnesium	158	188
Manganese	0.22	0.11
Mercury (μg/L)	0.5[b]	0.5[b]
Nickel (μg/L)	179	177
Potassium	14.4	12.8
Sodium	1665	1133
Zinc (μg/L)	70	177
Selenium (μg/L)	49	31

---

[a] Test and control sites are significantly different at the 0.05 level.

[b] Concentrations below detection limit indicated.

TABLE 15. MEAN CONCENTRATIONS OF PARAMETERS IN TEST AND CONTROL SITE GROUNDWATERS SAMPLED JANUARY, 1977 (DEPTH LESS THAN 30 METERS)

Parameter	Means (mg/L unless noted) Control	 Test
Dissolved Oxygen	1.2	2.4
pH	7.3	7.3
Conductivity	9405	7943
Total Alkalinity	204	294[a]
Dissolved Solids	3718	5949
Biochemical Oxygen Demand	1[b]	1[b]
Chemical Oxygen Demand	59	42
Chloride	2957	2000
Sulfide-S	--	--
Total Coliform	19	58
Fecal Coliform	0	6
Total Organic C	--	--
Dissolved Organic C	--	7.7
Total Organic N	--	--
Soluble Organic N	0.5	0.6
Ammonium-N	0.2	0.1
Nitrate-N	0.1	5.3
Total Phosphorus	--	--
Soluble Phosphorus	0.04	0.05
Soluble Orthophosphate	0.04	0.04
Sulfate	2272	1749
Aluminum	0.6	1.7
Arsenic (μg/L)	26	20[b]
Boron (μg/L)	215	270
Cadmium (μg/L)	20[b]	20[b]
Calcium	343	368
Cobalt (μg/L)	50[b]	50[b]
Chromium (μg/L)	39	27
Copper (μg/L)	20[b]	20[b]
Iron	0.5[b]	1.5
Lead (μg/L)	100[b]	100[b]
Magnesium	175	216
Manganese	0.12	0.08
Mercury (μg/L)	0.5[b]	0.5[b]
Nickel (μg/L)	50[b]	50[b]
Potassium	8.5	7.1
Sodium	1756	1183
Zinc (μg/L)	50[b]	76
Selenium (μg/L)	36	28

[a] Test and control sites are significantly different at the 0.05 level.

[b] Concentrations below detection limit indicated.

TABLE 16. MEAN CONCENTRATIONS OF PARAMETERS IN TEST AND CONTROL SITE GROUNDWATERS SAMPLED APRIL, 1977 (DEPTH LESS THAN 30 METERS)

Parameter	Means (mg/L unless noted)	
	Control	Test
Dissolved Oxygen	2.4	1.9
pH	7.5	7.1[a]
Conductivity	9192	7222
Total Alkalinity	229	311
Dissolved Solids	7654	6103
Biochemical Oxygen Demand	1[b]	1[b]
Chemical Oxygen Demand	14	25
Chloride	2577	1810
Sulfide-S	0.1[b]	0.1[b]
Total Coliform	TNTC[c]	890
Fecal Coliform	7	1
Total Organic C	--	--
Dissolved Organic C	13.6	13.4
Total Organic N	--	--
Soluble Organic N	1.0	0.6
Ammonium-N	1.1	0.5
Nitrate-N	0.1[b]	7.0
Total Phosphorus	--	--
Soluble Phosphorus	0.06	0.03
Soluble Orthophosphate	0.02	0.02
Sulfate	1796	1811
Aluminum	0.3[b]	0.3[b]
Arsenic (μg/L)	20[b]	20[b]
Boron (μg/L)	244	371
Cadmium (μg/L)	20[b]	20[b]
Calcium	611	642
Cobalt (μg/L)	--	--
Chromium (μg/L)	20[b]	20[b]
Copper (μg/L)	20[b]	20[b]
Iron	0.8	0.5[b]
Lead (μg/L)	--	--
Magnesium	153	170
Manganese	0.25	0.09
Mercury (μg/L)	--	--
Nickel (μg/L)	50[b]	50[b]
Potassium	16.6	11.9
Sodium	1750	1102
Zinc (μg/L)	186	111
Selenium (μg/L)	71	31[a]

[a] Test and control sites are significantly different at the 0.05 level.

[b] Concentrations below detection limit indicated.

[c] At least one sample analyzed too numerous to count.

In the next analysis, only the test wells with depths approximately greater than 20 feet were compared to the control site wells. This provided a comparison of wells with similar average depths by excluding the shallow test site wells included in the previous analysis. Table 17 contains the results for the composite means for all rounds and shows that total alkalinity and nitrate were the only parameters found to be in significantly greater concentration at the test site than at the control site at the 0.05 level of significance. These are the same parameters identified by the previous analysis. Also, Table 17 shows the means for pH, chlorides, sodium, and selenium were significantly greater at the 0.05 level in the groundwater at the control site than in the deeper test site wells. All other parameters showed no significant difference between the control and test sites at the 0.05 level. It is further emphasized that mean concentrations for all metals at the test site were either at or below the detection limit or showed no significant difference at the 0.05 level with the exception of selenium, which was significantly greater in the groundwater found below the control site. As before, the wells were compared on an individual round basis; the results are presented in Tables 18 through 21. For round one (Table 18), pH was found to be significantly greater at the control site than at the test site. All other parameters show no significant difference. Table 19 shows calcium to be the only parameter in round two with a significant difference in the means with the greater concentration (703 mg/L vs. 505 mg/L) in the groundwater at the test site. For round three no significant difference existed for any parameter at the 0.05 level (Table 20). Table 21 shows soluble phosphorus and selenium at significantly greater concentrations at the control site than at the test site in round four with no significant difference for the remaining parameters. In summary, for this analysis, nitrate and alkalinity were the only parameters identified to be in significantly greater concentrations at the 0.05 level in the groundwater at the test site than in the groundwater at the control site.

A summary of the parameters with significant differences in the means between the test site and control site at the 0.05 level is shown in Table 22. The alkalinity of the effluent water used for irrigation at the test site was significantly greater than the alkalinity of the irrigation water at the control site. This difference was also observed in the groundwaters between the sites.

It is interesting to note that although the ammonia concentration in the irrigation effluent at the test site was significantly higher than in the irrigation water at the control site, the difference was not significant in the groundwater. In contrast, the nitrate concentration in the irrigation water was not significantly different from test site to control site but was significantly different in the groundwater in both well comparisons. A possible explanation is that nitrification in the upper soil layers changed the ammonia to nitrate with the excess nitrate leaching to the groundwater.

Another trend observed was evident in the phosphate, potassium, and COD data. The analysis showed that total phosphate, soluble phosphate, soluble orthophosphate, COD, and potassium concentrations were significantly greater in the irrigation effluent at the test site compared to the irrigation water at the control site. However, these differences were not significant in the

TABLE 17. MEAN CONCENTRATIONS OF PARAMETERS IN TEST AND CONTROL SITE GROUNDWATERS (DEPTH GREATER THAN 6 METERS)

Parameter	Means (mg/L unless noted)	
	Control	Test
Dissolved Oxygen	1.6	1.9
pH	7.3	7.1[a]
Conductivity	9260	8197
Total Alkalinity	220	328[a]
Dissolved Solids	6392	6396
Biochemical Oxygen Demand	1[b]	1[b]
Chemical Oxygen Demand	45	58
Chloride	2514	1904[a]
Sulfide-S	0.1[b]	0.1[b]
Total Coliform	TNTC[c]	TNTC
Fecal Coliform	2	6
Total Organic C	--	--
Dissolved Organic C	11.6	15.0
Total Organic N	--	--
Soluble Organic N	0.8	0.8
Ammonium-N	0.4	0.2
Nitrate-N	1.0	6.5[a]
Total Phosphorus	--	--
Soluble Phosphorus	0.55	0.38
Soluble Orthophosphate	0.11	0.21
Sulfate	1979	1905
Aluminum	1.1	0.9
Arsenic (μg/L)	26	20[b]
Boron (μg/L)	245	353
Cadmium (μg/L)	20[b]	20[b]
Calcium	436	550
Cobalt (μg/L)	50[b]	50[b]
Chromium (μg/L)	20[b]	20[b]
Copper (μg/L)	53	65
Iron	7.5	3.4
Lead (μg/L)	100[b]	100[b]
Magnesium	150	173
Manganese	0.15	0.11
Mercury (μg/L)	0.5[b]	0.5[b]
Nickel (μg/L)	63	68
Potassium	11.9	9.4
Sodium	1653	1122[a]
Zinc (μg/L)	86	117
Selenium (μg/L)	52	30[a]

[a] Test and control sites are significantly different at the 0.05 level.

[b] Concentrations below detection limit indicated.

[c] At least one sample analyzed too numerous to count.

TABLE 18. MEAN CONCENTRATIONS OF PARAMETERS IN TEST AND CONTROL SITE GROUNDWATERS SAMPLED JUNE, 1976 (DEPTH GREATER THAN 6 METERS)

Parameter	Means (mg/L unless noted) Control	Test
Dissolved Oxygen	1.1	2.0
pH	7.2	6.8[a]
Conductivity	7910	8083
Total Alkalinity	246	389
Dissolved Solids	6073	6750
Biochemical Oxygen Demand	1[b]	1[b]
Chemical Oxygen Demand	36	97
Chloride	2070	1863
Sulfide-S	--	--
Total Coliform	TNTC[c]	TNTC
Fecal Coliform	0	11
Total Organic C	--	--
Dissolved Organic C	--	21.5
Total Organic N	--	--
Soluble Organic N	1.7	1.4
Ammonium-N	0.1[b]	0.1[b]
Nitrate-N	1.5	8.7
Total Phosphorus	--	--
Soluble Phosphorus	2.05	1.38
Soluble Orthophosphate	0.34	0.72
Sulfate	--	--
Aluminum	1.6	1.9
Arsenic (μg/L)	--	--
Boron (μg/L)	230	211
Cadmium (μg/L)	20[b]	20[b]
Calcium	288	441
Cobalt (μg/L)	50[b]	50[b]
Chromium (μg/L)	20[b]	20[b]
Copper (μg/L)	170	202
Iron	2.0	1.8
Lead (μg/L)	100[b]	100[b]
Magnesium	115	87
Manganese	0.05[b]	0.05[b]
Mercury (μg/L)	0.5[b]	0.5[b]
Nickel (μg/L)	50[b]	50[b]
Potassium	8.2	6.7
Sodium	1443	948
Zinc (μg/L)	50[b]	133
Selenium (μg/L)	--	--

[a] Test and control sites are significantly different at the 0.05 level.

[b] Concentrations below detection limit indicated.

[c] At least one sample analyzed too numerous to count.

TABLE 19. MEAN CONCENTRATIONS OF PARAMETERS IN TEST AND CONTROL SITE GROUNDWATERS SAMPLED OCTOBER, 1976 (DEPTH GREATER THAN 6 METERS)

Parameter	Means (mg/L unless noted) Control	 Test
Dissolved Oxygen	1.9	1.3
pH	7.4	7.1
Conductivity	10,535	9184
Total Alkalinity	200	364
Dissolved Solids	6788	6429
Biochemical Oxygen Demand	1[b]	1[b]
Chemical Oxygen Demand	70	70
Chloride	2452	1837
Sulfide-S	--	--
Total Coliform	0	0
Fecal Coliform	0	0
Total Organic C	--	--
Dissolved Organic C	7.7	--
Total Organic N	--	--
Soluble Organic N	0.2	0.4
Ammonium-N	0.5	0.1[b]
Nitrate-N	2.5	8.0
Total Phosphorus	--	--
Soluble Phosphorus	0.04	0.06
Soluble Orthophosphate	0.04	0.05
Sulfate	2016	2211
Aluminum	1.8	0.5
Arsenic (μg/L)	37	20[b]
Boron (μg/L)	293	645
Cadmium (μg/L)	20[b]	20[b]
Calcium	505	703[a]
Cobalt (μg/L)	50[b]	50[b]
Chromium (μg/L)	24	20[b]
Copper (μg/L)	20[b]	24
Iron	27	10
Lead (μg/L)	100[b]	100[b]
Magnesium	158	214
Manganese	0.22	0.11
Mercury (μg/L)	0.5[b]	0.5[b]
Nickel (μg/L)	179	199
Potassium	14.4	12.8
Sodium	1665	1275
Zinc (μg/L)	70	186
Selenium (μg/L)	49	32

[a] Test and control sites are significantly different at the 0.05 level.

[b] Concentrations below detection limit indicated.

TABLE 20. MEAN CONCENTRATIONS OF PARAMETERS IN TEST AND CONTROL SITE GROUNDWATERS SAMPLED JANUARY, 1977 (DEPTH GREATER THAN 6 METERS)

Parameter	Means (mg/L unless noted)	
	Control	Test
Dissolved Oxygen	1.2	2.2
pH	7.3	7.3
Conductivity	9405	7839
Total Alkalinity	204	271
Dissolved Solids	3718	5936
Biochemical Oxygen Demand	1^b	1^b
Chemical Oxygen Demand	59	42
Chloride	2957	1912
Sulfide-S	--	--
Total Coliform	19	43
Fecal Coliform	0	11
Total Organic C	--	--
Dissolved Organic C	--	--
Total Organic N	--	--
Soluble Organic N	0.5	0.9
Ammonium-N	0.2	0.2
Nitrate-N	0.1^b	2.7
Total Phosphorus	--	--
Soluble Phosphorus	0.04	0.06
Soluble Orthophosphate	0.04	0.04
Sulfate	2272	1617
Aluminum	0.6	1.1
Arsenic (μg/L)	26	20^b
Boron (μg/L)	215	224
Cadmium (μg/L)	20^b	20^b
Calcium	343	362
Cobalt (μg/L)	50^b	50^b
Chromium (μg/L)	39	26
Copper (μg/L)	20^b	20^b
Iron	0.5^b	1.0
Lead (μg/L)	100^b	100^b
Magnesium	175	206
Manganese	0.12	0.08
Mercury (μg/L)	0.5^b	0.5^b
Nickel (μg/L)	50^b	50^b
Potassium	8.5	5.6
Sodium	1756	1112
Zinc (μg/L)	50^b	50^b
Selenium (μg/L)	36	26

[b] Concentrations below detection limit indicated.

TABLE 21. MEAN CONCENTRATIONS OF PARAMETERS IN TEST AND CONTROL SITE GROUNDWATERS SAMPLED APRIL, 1977 (DEPTH GREATER THAN 6 METERS)

Parameter	Means (mg/L unless noted)	
	Control	Test
Dissolved Oxygen	2.4	2.5
pH	7.5	7.2
Conductivity	9192	7682
Total Alkalinity	229	288
Dissolved Solids	7654	6471
Biochemical Oxygen Demand	1[b]	1[b]
Chemical Oxygen Demand	14	23
Chloride	2577	2007
Sulfide-S	0.1[b]	0.1[b]
Total Coliform	TNTC[c]	57
Fecal Coliform	7	1
Total Organic C	--	--
Dissolved Organic C	13.6	10.6
Total Organic N	--	--
Soluble Organic N	1.0	0.3
Ammonium-N	1.1	0.4
Nitrate-N	0.1[b]	6.5
Total Phosphorus	--	--
Soluble Phosphorus	0.06	0.03[a]
Soluble Orthophosphate	0.02	0.01
Sulfate	1796	1883
Aluminum	0.3[b]	0.3[b]
Arsenic (μg/L)	20[b]	20[b]
Boron (μg/L)	244	332
Cadmium (μg/L)	20[b]	20[b]
Calcium	611	664
Cobalt (μg/L)	--	--
Chromium (μg/L)	20[b]	20[b]
Copper (μg/L)	20[b]	20[b]
Iron	0.8	0.5[b]
Lead (μg/L)	--	--
Magnesium	153	184
Manganese	0.25	0.10
Mercury (μg/L)	--	--
Nickel (μg/L)	50[b]	50[b]
Potassium	16.6	12.4
Sodium	1750	1152
Zinc (μg/L)	186	94
Selenium (μg/L)	71	33[a]

[a] Test and control sites are significantly different at the 0.05 level.

[b] Concentrations below detection limit indicated.

[c] At least one sample analyzed too numerous to count.

TABLE 22. ANALYSIS SUMMARY

Parameter	Test Site Irrigation Water vs. Control Site Irrigation Water (Table 11)	Test Site Groundwater All Wells, All Rounds vs. Control Site Groundwater (Table 12)	Test Site Groundwater Deep Wells, All Rounds vs. Control Site Groundwater (Table 17)
Dissolved Oxygen			
pH		C[a]	C
Conductivity			
Total Alkalinity	T[b]	T	T
Dissolved Solids	C		
Biochemical Oxygen Demand			
Chemical Oxygen Demand	T		
Chloride		C	C
Sulfide-S			
Total Coliform			
Fecal Coliform			
Dissolved Organic C			
Soluble Organic N			
Ammonium-N	T	C	
Nitrate-N		T	T
Total Phosphorus	T		
Soluble Phosphorus	T		
Soluble Orthophosphate	T		
Sulfate			
Aluminum			
Arsenic			
Boron			
Cadmium			
Calcium			
Cobalt			
Chromium			
Copper			
Iron			
Lead			
Magnesium			
Manganese			
Mercury			
Nickel			
Potassium	T		
Sodium		C	C
Zinc			
Selenium		C	C

[a] C - Significant difference at the 0.05 level with the concentration higher at the control site.

[b] T - Significant difference at the 0.05 level with the concentration higher at the test site.

groundwater comparisons, indicating that the phosphorus, potassium, and organics were adsorbed in the soil, microbially reduced, or utilized by the plants before the percolate reached the groundwater.

In addition, the blank spaces in Table 22 shown for the remaining parameters indicated that either no significant difference existed between irrigation effluent at the test site and irrigation water at the control site or the concentration in the control site irrigation water was greater than the test site irrigation water. The same was true for the comparisons between groundwaters at the test and control sites.

A statistical comparison of the means of the water quality parameters for wells at varying depths at the test site was made. Wells at the test site were arbitrarily grouped as those having a screened depth greater than 6 m (20 ft) and less than 6 m (20 ft). Sample means calculated for the two groups appear in Table 23. As in the previous analyses, the method of pooled variances was used to compare the various means of the two groups for significant differences at the 0.05 level. Table 23 shows nitrate to be the only parameter found to be significantly different at the 0.05 level for the two groups with a sample mean concentration of 13 mg/L for wells less than 6 m (20 ft) deep and a sample mean concentration of 6.5 mg/L for wells greater than 6 m (20 ft) deep. All other parameters show no significant change with depth in the groundwater at the test site.

The final statistical comparison was the evaluation of the significance of changes in various parameter concentrations as a function of season for groundwater at the test site. The test site wells were grouped as in the previous analysis. For each group an analysis was performed to determine if differences in mean parameter concentrations were significant at the 0.05 level from round one to round two, round two to round three, and round three to round four. The results of the analysis are shown in Table 24.

For the shallower wells (<6 m), 9 out of 35 parameters showed a significant difference in mean values for at least one of the three comparisons made, and only 1 of 37 (calcium) showed significant differences for all three comparisons. For the deeper wells, 12 of 35 parameters showed significant differences at the 0.05 level for at least one of the three comparisons with no parameter having significant differences for all three comparisons. Overall, 15 of 35 parameters were found to have significant differences seasonally for at least one comparison.

These results serve to emphasize the necessity for an effective monitoring program to include sampling during all seasons of the year, as significant changes in quality were found to occur for a number of parameters. The seasonal changes occur as a result of a number of interactions including groundwater movement below the site, fluctuations in groundwater level in and out of the capillary zone, changes in quantity and quality characteristics of percolating irrigation water, and rainfall recharge. For example, the increase in chloride concentration and simultaneous decrease in nitrate concentration observed from round two to round three could possibly reflect dilution with water from another origin with higher chloride concentrations and/or changes in quality of percolating water coinciding with the end of the irriga-

TABLE 23. MEAN CONCENTRATIONS OF PARAMETERS IN TEST SITE GROUNDWATERS

Parameter	Means (mg/L unless noted) <6 Meters	Means (mg/L unless noted) >6 Meters
Dissolved Oxygen	2.1	1.9
pH	7.1	7.1
Conductivity	7431	8197
Total Alkalinity	323	328
Dissolved Solids	5807	6396
Biochemical Oxygen Demand	1[b]	1[b]
Chemical Oxygen Demand	46	58
Chloride	1673	1904
Sulfide-S	0.1[b]	0.1[b]
Total Coliform	TNTC[c]	TNTC
Fecal Coliform	52	6
Total Organic C	--	--
Dissolved Organic C	13.2	15.0
Total Organic N	--	--
Soluble Organic N	0.7	0.8
Ammonium-N	0.2	0.2
Nitrate-N	13.0	6.5[a]
Total Phosphorus	--	--
Soluble Phosphorus	0.39	0.38
Soluble Orthophosphate	0.08	0.21
Sulfate	1842	1905
Aluminum	1.4	0.9
Arsenic (μg/L)	20[b]	20[b]
Boron (μg/L)	397	353
Cadmium (μg/L)	20[b]	20[b]
Calcium	503	550
Cobalt (μg/L)	50[b]	50[b]
Chromium (μg/L)	20[b]	20[b]
Copper (μg/L)	61	65
Iron	95.8	3.4
Lead (μg/L)	100[b]	100[b]
Magnesium	160	173
Manganese	0.11	0.11
Mercury (μg/L)	0.5[b]	0.5[b]
Nickel (μg/L)	62	68
Potassium	10.0	9.4
Sodium	1073	1122
Zinc (μg/L)	137	117
Selenium (μg/L)	29	30

[a] Significant difference at the 0.05 level.

[b] Concentrations below detection limit indicated.

[c] At least one sample analyzed too numerous to count.

TABLE 24. SEASONAL VARIATION OF MEAN CONCENTRATIONS OF VARIOUS PARAMETERS IN GROUNDWATER AT THE TEST SITE, ROSWELL, NEW MEXICO

	Round 1 vs. Round 2		Round 2 vs. Round 3		Round 3 vs. Round 4	
	Well Depth		Well Depth		Well Depth	
Parameter	<6 m	>6 m	<6 m	>6 m	<6 m	>6 m
Dissolved Oxygen						
pH		I				
Conductivity						
Total Alkalinity						
Dissolved Solids						
Biochemical Oxygen Demand	a	a	a	a	a	a
Chemical Oxygen Demand				D		
Chloride			I			
Total Coliform	TNTC[c]	TNTC				
Fecal Coliform						
Dissolved Organic C		-				
Soluble Organic N	D	D				
Ammonium-N	a	a	a	a	a	I
Nitrate-N			D			
Soluble Phosphorus	D	D				
Soluble Orthophosphate	D				D	a
Sulfate	-	-				
Aluminum		D			a	a
Arsenic	a	a	a	a		a
Boron	I	I	D	D	a	
Cadmium	a	a	a	a	a	a
Calcium	I	I	D	D	I	I
Cobalt	a	a	a	a	a	a
Chromium	a	a	a	a	a	a
Copper	a	D	a	a	a	a
Iron		I			a	a
Lead	a	a	a	a	a	a
Magnesium	I	I	I		D	
Manganese						
Mercury	a	a	a	a	a	a
Nickel	a	a	a	a	a	a
Potassium	I	I	D	D		I
Sodium						
Zinc						
Selenium	-	-				

[I] Significant difference at 0.05 level with increase in mean concentration.

[a] Mean concentrations below detection limits.

[D] Significant difference at 0.05 level with decrease in mean concentration.

[c] At least one sample analyzed too numerous to count.

tion season. The effects of the interactions are further exemplified in Figure 13, where means for selected parameters from Table 24 found to have significant seasonal changes are depicted.

The salient groundwater quality parameters that were differentiable between the test and control sites are discussed in more detail in the following paragraphs. In all cases, these parameters were present in the irrigation effluent at concentrations markedly greater than occurred in incident precipitation. The complete list and data for groundwater quality parameters, including those for which no significant differences were observed between the test and control sites, are tabulated in Appendix B.

Nitrogen--

Ammonium nitrogen concentrations ranged from less than 0.1 to 2.1 mg/L at the control sites and from less than 0.1 to 0.8 mg/L at the test site (Figure 14). The higher concentrations were generally and unexplainably observed in the April, 1977, samples at both the test and control sites. There was no correlation of concentrations with depth. The average of 12 analyses at the control site was <0.35 mg/L and <0.21 mg/L for 51 analyses at the test site. Thus, ammonium nitrogen was not present in higher concentrations in this test site groundwater as a result of effluent irrigation.

Soluble organic nitrogen concentrations ranged from less than 0.1 to 2.0 mg/L at the control sites and from less than 0.1 to 4.2 mg/L at the test site (Figure 15). A trend with sampling period was generally observed at both the control and test sites with maximum concentrations being observed for the June, 1976, and April, 1977, periods and minimum concentrations usually corresponding with the October, 1976, sampling. A seasonal correlation is possible but is not readily explainable. There was no correlation between concentrations and depth. The average of 12 analyses at the control site was less than 0.84 mg/L and 51 analyses at the test site was less than 0.75 mg/L. Thus, soluble organic nitrogen was not present in higher concentrations in the test site groundwater as a result of effluent irrigation.

The observations regarding nitrate nitrogen, however, were more complex. Although the analytical method for measuring nitrate nitrogen was changed on the third sampling round, all data were considered valid. The possibility does exist that the higher values for nitrate nitrogen on the first two rounds were due to analytical problems.

Test site well numbers 12150, 12210, 12090, 12170, 12201, 12202, 12203, and 12130 (Figures 12 and 16) all showed relatively high nitrate nitrogen in the general range of 5 to 30 mg/L with an average concentration of less than 13.6 mg/L. These wells were located on the west and north perimeter of the test site.

Alternatively, test site well numbers 12160, 12050, 12043, 12030, and 12140 showed relatively lower nitrate nitrogen concentrations in the range of 0 to 8 mg/L. These wells were located in the south, east, and central region of the test site. The existence of a decided nitrate nitrogen gradient indicated a source of nitrate nitrogen to groundwater at the west and north boundaries of the test site (Figure 17). It is possible that the combined

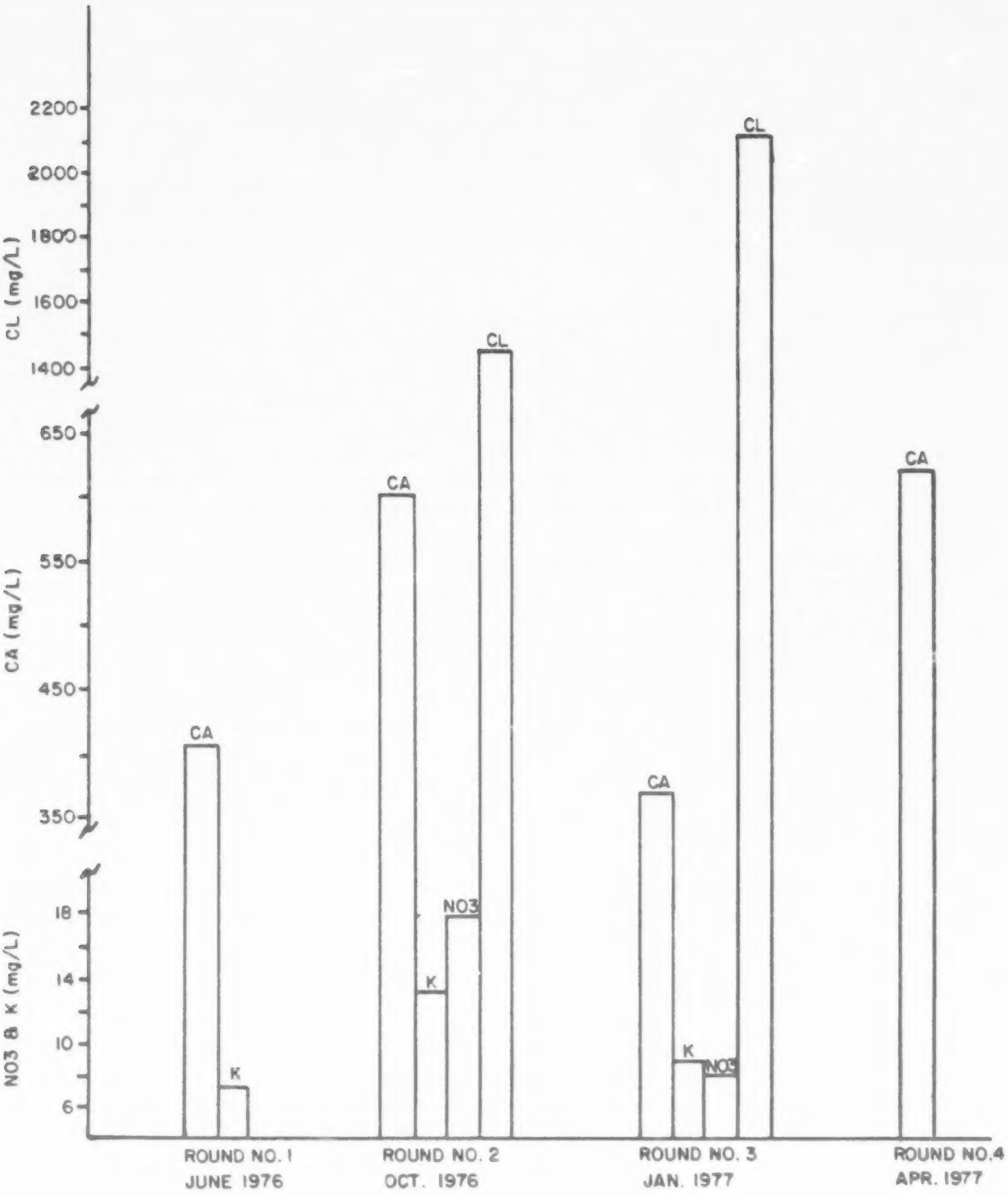
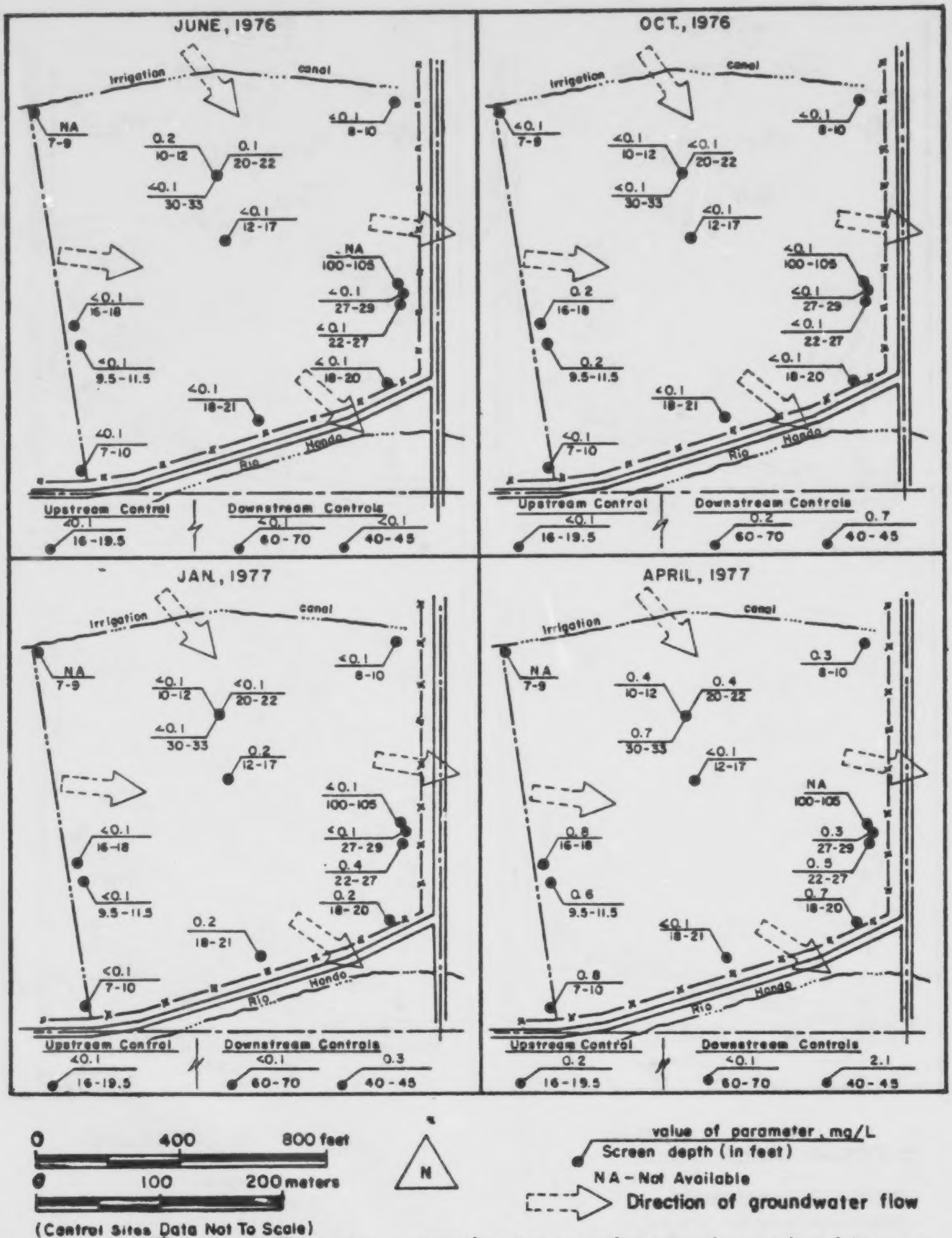


Figure 13. Means of selected parameters for which seasonal changes shown were significant at the 0.05 level.



(Control Sites Data Not To Scale)

Figure 14. Test site groundwater constituents - Ammonium Nitrogen.

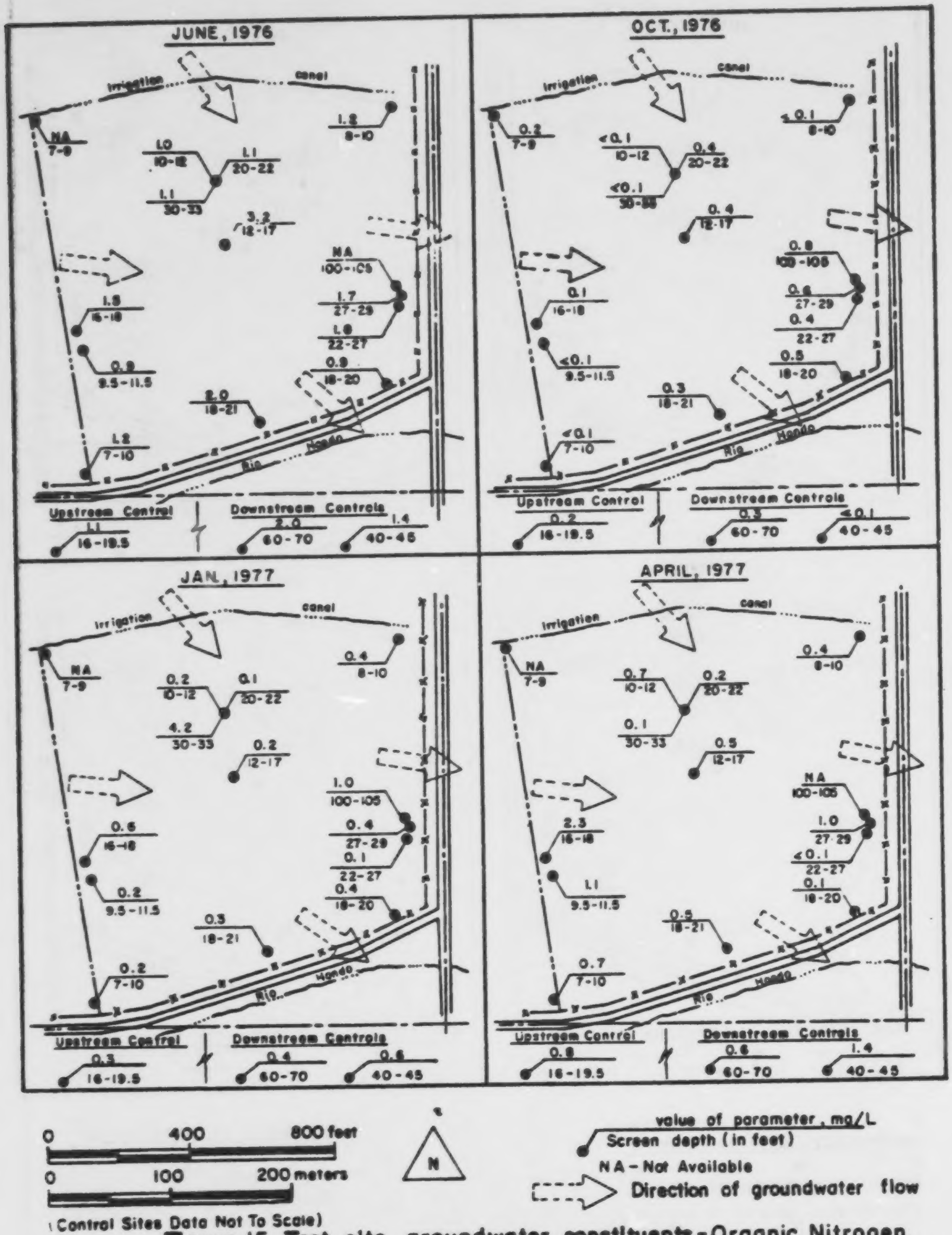


Figure 15. Test site groundwater constituents-Organic Nitrogen.

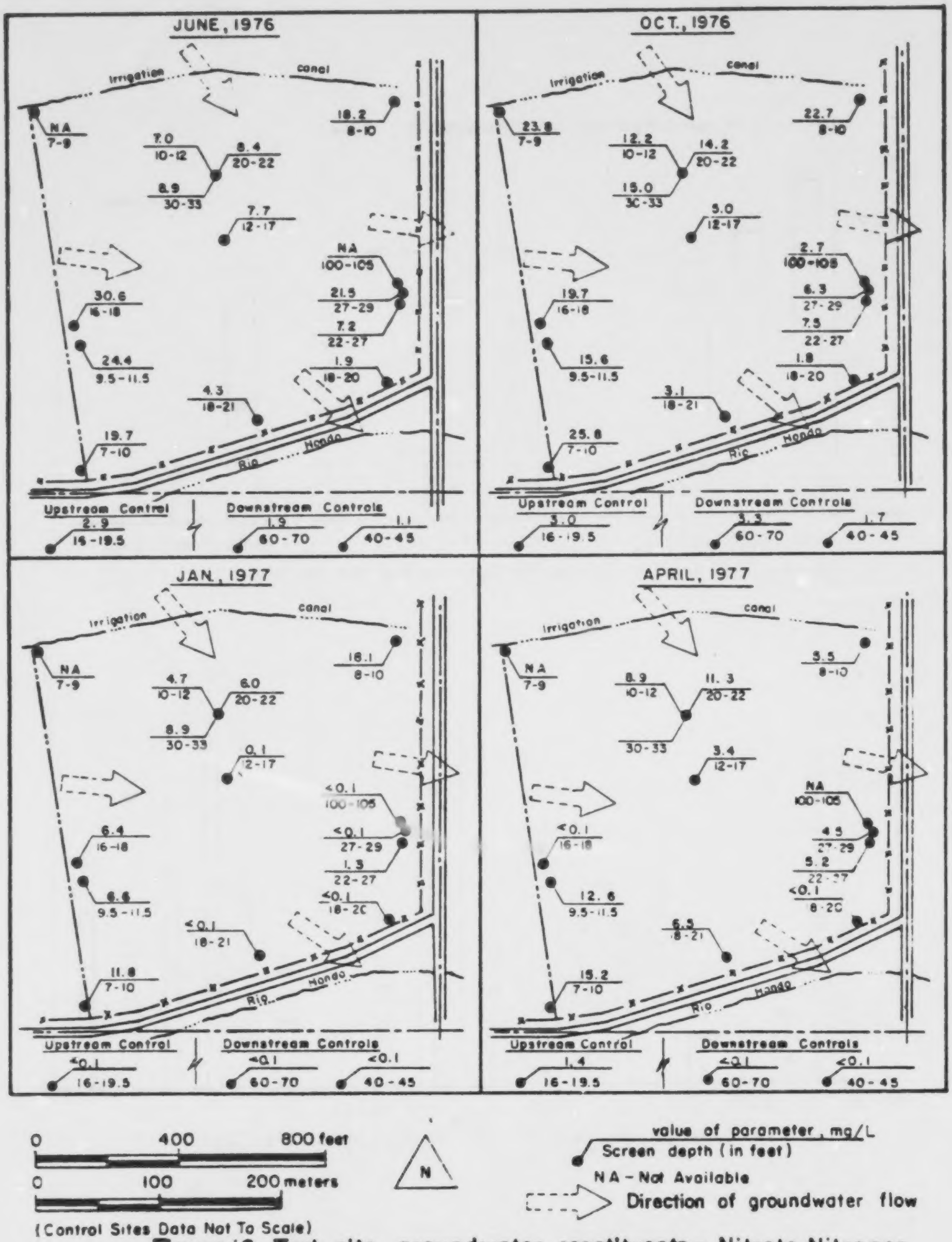


Figure 16. Test site groundwater constituents – Nitrate Nitrogen.

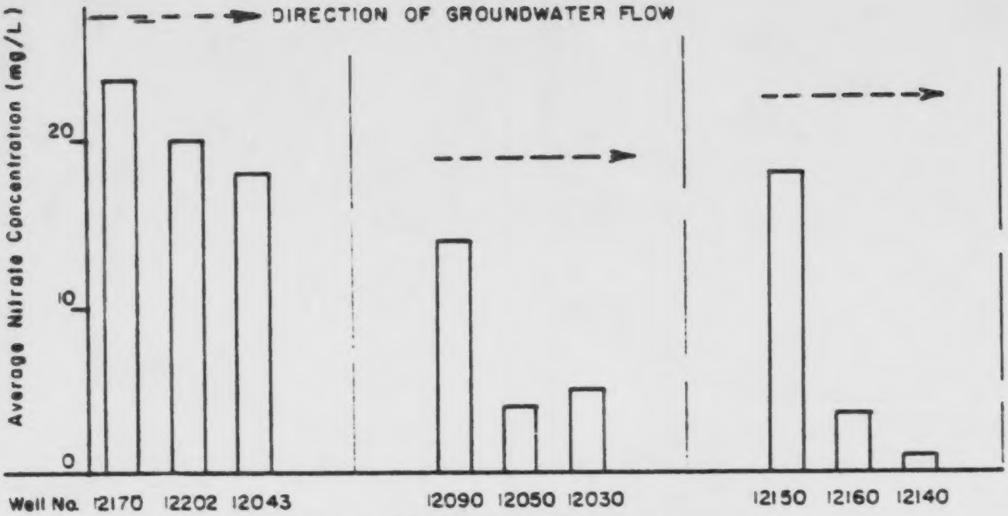


Figure 17. Change in Nitrate Nitrogen across the test site.

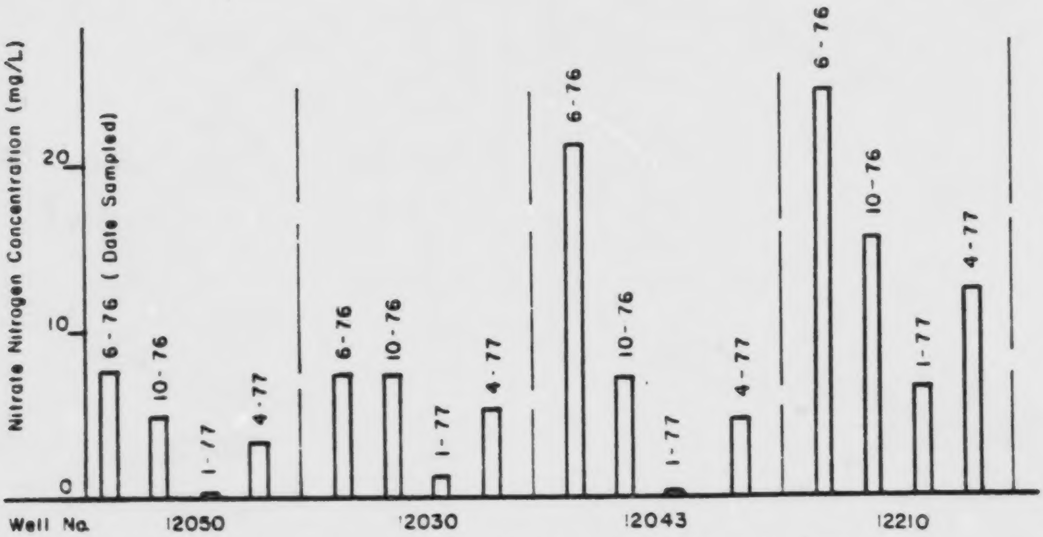


Figure 18. Seasonal change in Nitrate Nitrogen at the test Site.

sludge plus effluent application site to the west and north of the test site was responsible for this nitrate nitrogen.

The lower nitrate nitrogen concentrations in the monitoring wells in the downgradient area of the test site led to the conclusion that the irrigation recharge occurring on the test site was sufficiently stripped of nitrate nitrogen so that this recharge acted as a diluent for the upstream nitrate nitrogen flows. Thus, nitrate nitrogen removal performance as a by-product of effluent irrigation on the test site appeared to be satisfactory with an average residual nitrate nitrogen concentration of less than 4.4 mg/L being achieved. This was in the general range of the concentrations observed at the control wells 11030, 11050, and 11060, which had an average nitrate nitrogen concentration of less than 1.3 mg/L and a concentration range of <0.1 to 3.3 mg/L. The average total nitrogen concentration in the irrigation effluent was 42.2 mg/L and in the irrigation well water was 2.7 mg/L.

The nitrate nitrogen data demonstrated other noteworthy characteristics. At a given well location and at different sampling times, it appeared that nitrification activity can be correlated with the season of the year. For example, in wells 12050, 12030, 12043, and 12210, the nitrate nitrogen concentration was at a minimum in January, 1977, which suggested minimum winter nitrification activity (Figure 18).

Denitrification possibilities from travel through the saturated zone were examined. Sufficient organic constituents were present, as evidenced by the relatively high COD concentrations, to potentially serve as the carbon source for denitrification. While the nitrate nitrogen concentration of the groundwater decreased across the site as previously indicated, there was not a corresponding decrease in organic constituents, as evidenced by a relatively constant COD concentration. It was therefore concluded that denitrification was not occurring to any marked extent in the saturated zone.

A final complicating evapotranspiration phenomenon should be mentioned for nitrate nitrogen as it was applicable to all groundwater parameters capable of downward migration. Given the 25 percent recharge that was projected to be occurring as a result of irrigation (i.e., 0.20 m (8 in) of net recharge from 0.80 m (32 in) of irrigation), the actual treatment performance of the Roswell effluent irrigation system was equivalent to removing nitrate nitrogen to a residual that is less than 25 percent of an average 4.4 mg/L or to less than an average 1.1 mg/L of nitrate nitrogen for the original 0.80 m (32 in) effluent application.

Chemical Oxygen Demand (COD)--

The COD concentrations of the irrigation effluent have been identified earlier as abnormally high at 135 to 206 mg/L for a secondary effluent. A packing plant wastewater contribution to the Roswell municipal system has been identified as a possible source of organic constituents that are relatively slow to biodegrade.

The COD concentration of all test site groundwater samples averaged 52 mg/L and had a range from 12 to 169 mg/L (Figure 19). The COD concentration of all control site groundwater samples averaged 47 mg/L with a range of 12

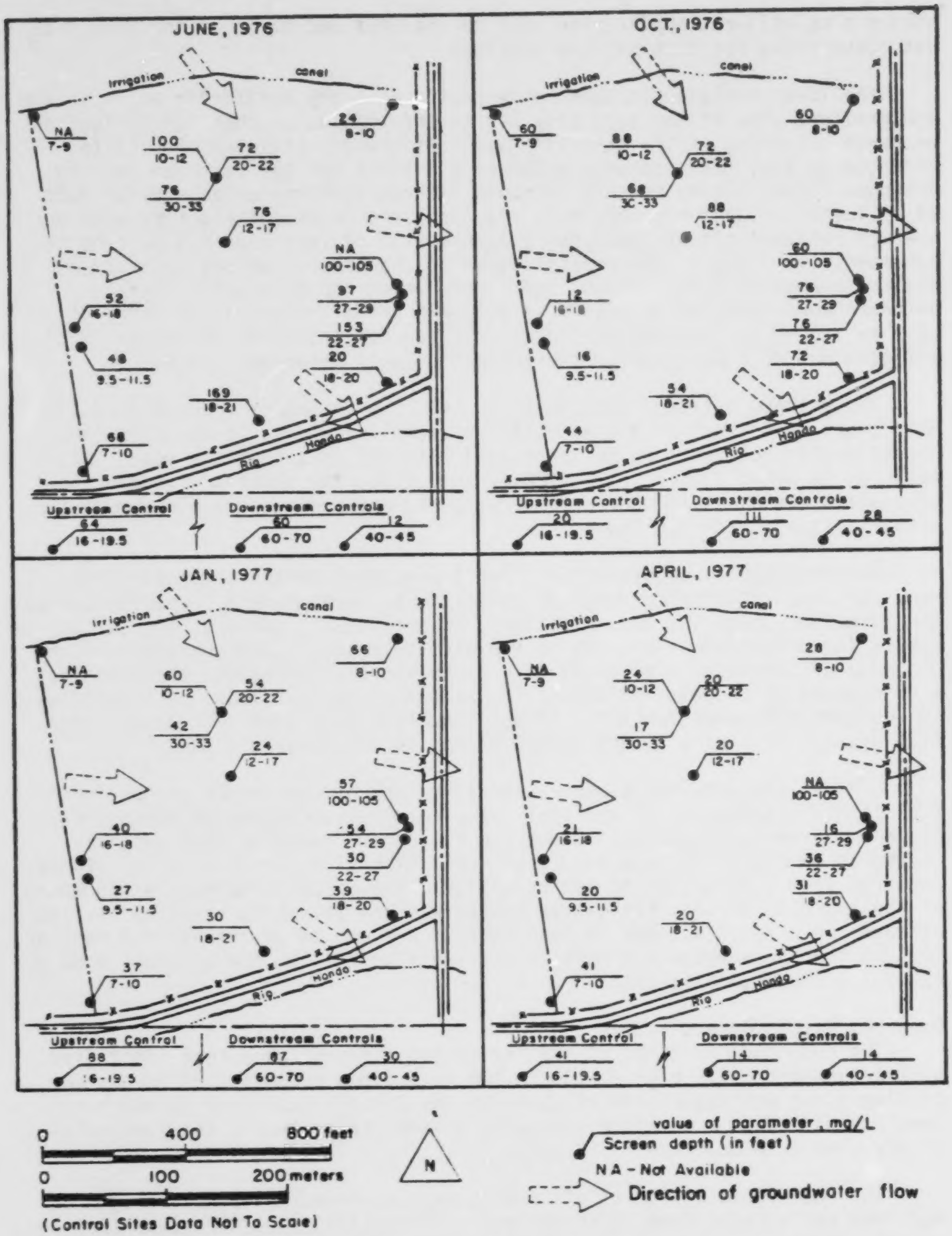


Figure 19. Test site groundwater constituents-Chemical Oxygen Demand.

to 111 mg/L. The average COD concentration for the irrigation effluent was 172 mg/L and for the irrigation groundwater was 29.0 mg/L. Thus, the average COD concentration in the control site groundwater was within 10 percent of the test site average groundwater concentration.

COD concentrations at the test site were highest for the June, 1976, sampling and tended to diminish in concentration for subsequent sampling dates (Figure 20). This correlated reasonably well with the March through July effluent irrigation schedule.

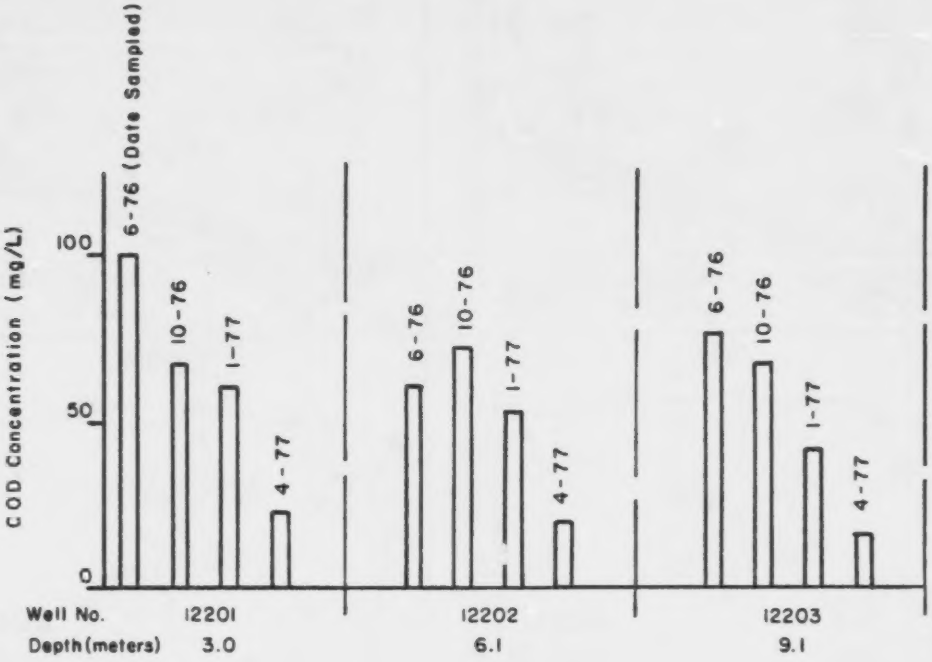


Figure 20. Seasonal and depth variations in COD at the test site.

Sodium, Chloride, Sulfate, Dissolved Solids--

The degree to which groundwater concentrations for sodium, chloride, sulfates, and dissolved solids were affected by soil geochemistry as contrasted with earlier and current irrigation practices was unclear. The concentrations of these parameters in the irrigation effluent were comparable to conventional irrigation water. Thus, it was assumed that with comparable irrigation practices upgradient from the test and control site using conventional and effluent irrigation water, similar increases in concentrations of these parameters would be observed in the groundwater at both test and control sites. This proved to be the case for dissolved solids, sulfate, sodium, and chloride. The dissolved solids and sulfate concentrations increased in the range of two to four times or from 2,000 to 4,000-8,000 mg/L and from 700 to 1,400-2,800 mg/L, respectively (Figure 21). The sodium and chloride concentrations increased in the range of one and one-half to four

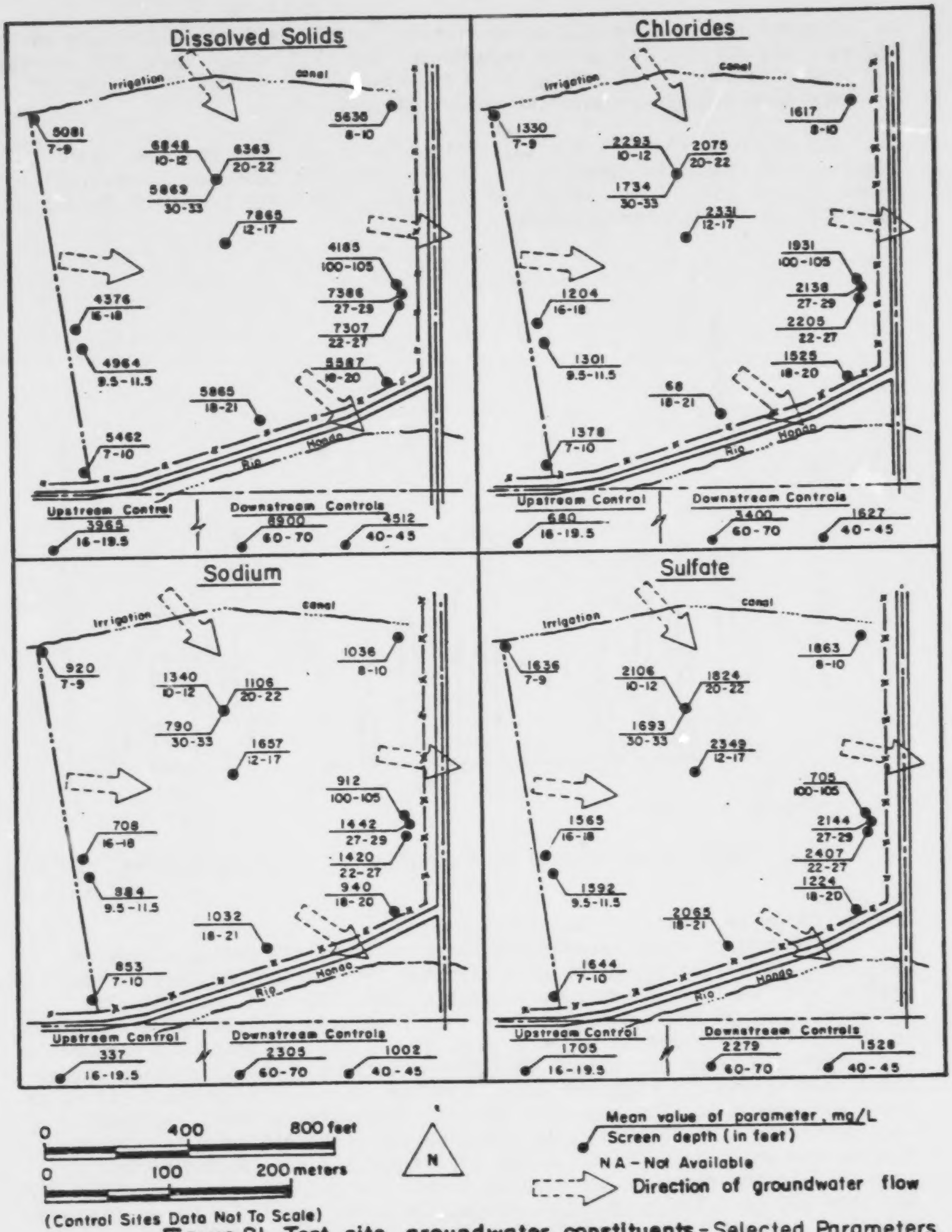


Figure 21. Test site groundwater constituents - Selected Parameters.

times, or from 400 to 600-2,400 mg/L and from 700 to 1,050-2,800 mg/L, respectively.

Possible conclusions from these results could be that (1) dissolved solids and sulfate concentrations were primarily determined by soil geochemical interactions and were relatively independent of current irrigation practice; (2) the increased sodium and chloride concentrations observed in the test and control site groundwaters were manifestations of evapotranspiration from the irrigation practices known to be occurring; and (3) given the groundwater conditions and irrigation practices that existed in the Roswell area, the increases in concentrations would occur in the groundwater as a result of the use of either effluent or conventional irrigation water.

Sodium and chloride pass through the soil column of a land treatment system relatively unchanged and could be termed conservative parameters. Sulfates and dissolved solids interact with the mineralized soils of the Roswell area and can be increased or decreased in concentration by passage through the soil column.

Phosphorus--

The phosphorus concentrations in the test site and control site wells and lysimeter were generally near minimum detectable levels compared with an average irrigation effluent concentration of total phosphorus of 8.0 mg/L. Thus, accumulation in the body of the soil could be anticipated. Detailed discussion of this interaction is presented in the subsequent section on the soil results. The lysimeter data for phosphorus samples 124104, 124202 through 124204, and 124302 through 124304 qualitatively indicated that phosphorus removal was still taking place over the upper 2 meters of soil horizon. The results were not quantitative because evaporative effects were not taken into account in the lysimeters.

Soluble phosphorus concentrations in groundwater ranged from 0.01 to 2.6 mg/L at the control sites and from <0.01 to 4.2 mg/L at the test site. Soluble orthophosphate phosphorus ranged from <0.01 to 0.37 mg/L at the control site and from <0.01 to 2.4 mg/L at the test site. The average soluble phosphorus concentrations were 0.55 mg/L (8 samples) at the control site and 0.38 mg/L (49 samples) at the test site. The average of 8 soluble orthophosphate phosphorus analyses at the control site was 0.11 mg/L and of 49 samples at the test site was 0.14 mg/L. For both parameters a statistical analysis (Table 12) showed no significant difference at the 0.05 level between the test and control sites.

Metals--

Groundwater was examined for the presence of the following metals--arsenic, cadmium, cobalt, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, and zinc. Except for iron, manganese, selenium, and zinc, which were low and comparable for the test and control sites, concentrations of metals were generally at or below minimum detectable levels.

Iron concentrations ranged from 0.3 to 1.6, manganese from <0.05 to 0.48, selenium from <0.010 to 0.083, and zinc from 0.05 to 0.20 mg/L at the control sites; iron concentrations ranged from <0.2 to 0.8, manganese from

<0.05 to 0.28, selenium from <0.010 to 0.062, and zinc from 0.020 to 0.35 mg/L at the test sites (Figure 22).

The averages of three iron, manganese, selenium, and zinc analyses at the control sites were 1.0, 0.26, 0.047, and 0.14 mg/L, respectively, and of 12 analyses at the test site were 0.38, 0.11, 0.031, and 0.11 mg/L, respectively.

There was no significant trend of metals concentrations between control and test sites with depth in groundwater or with location on the test site. The concentrations of iron, manganese, selenium, and zinc in the irrigation groundwater from the shallow aquifer were observed at <0.2, <0.05, <0.01, and <0.02 mg/L, respectively.

This determination was based on fourth round data. During the first three rounds, the groundwater samples for metals analysis were filtered only if the samples were turbid. Normally, the groundwater samples were clear with no solids visually present. However, due to the significant variance in metals data for the first three rounds, it was determined to filter all samples regardless of clarity during the fourth round.

Pesticides and Herbicides--

The chlorinated hydrocarbon pesticides and herbicides examined included endrin, lindane, methoxychlor, toxaphene, 2,4-D, and 2,4,5 TP silvex. Endrin, methoxychlor, and toxaphene were not observed at their respective detectable limits of 0.03, 0.01, and 0.1 ng/L at any time during this investigation.

The insecticide lindane occurred at a concentration in the range of <0.1 to 49 ng/L at the control sites and from <0.1 to 850 ng/L at the test site (Figure 23). The average of 12 analyses at the control sites was 10.5 ng/L and of 51 analyses at the test site was 74.3 ng/L. The irrigation effluent had a concentration range of 49 to 1,250 ng/L and an average concentration of 560 ng/L. Irrigation groundwater from the shallow aquifer had a concentration range of 1.3 to 72 ng/L and an average concentration of 26 ng/L. The high, sustained application rate associated with ridge-and-furrow irrigation together with the extremely slow rates of biodegradation for some chlorinated hydrocarbons may account for the apparent leakage of small amounts of lindane at the test site. However, the test site lindane concentration was well below the maximum contaminant level of 4,000 ng/L allowed by the current National Interim Primary Drinking Water Regulations.

The herbicide 2,4-D occurred at a concentration in the range of 0.4 to 46.4 ng/L at the control sites and from <0.4 to 88.5 ng/L at the test site (Figure 24). The average of 12 analyses at the control sites was 13.1 ng/L and of 48 analyses at the test site was 10.4 ng/L. The irrigation effluent had a concentration range of 0.6 to 64 ng/L and an average concentration of 29 ng/L. Irrigation groundwater from the shallow aquifer had a concentration range of 0.6 to 18.4 ng/L and an average concentration of 7.6 ng/L. No significant difference was thus observed between the test and control sites. Current National Interim Primary Drinking Water Regulations specify a maximum contaminant level for 2,4-D of 100,000 ng/L.

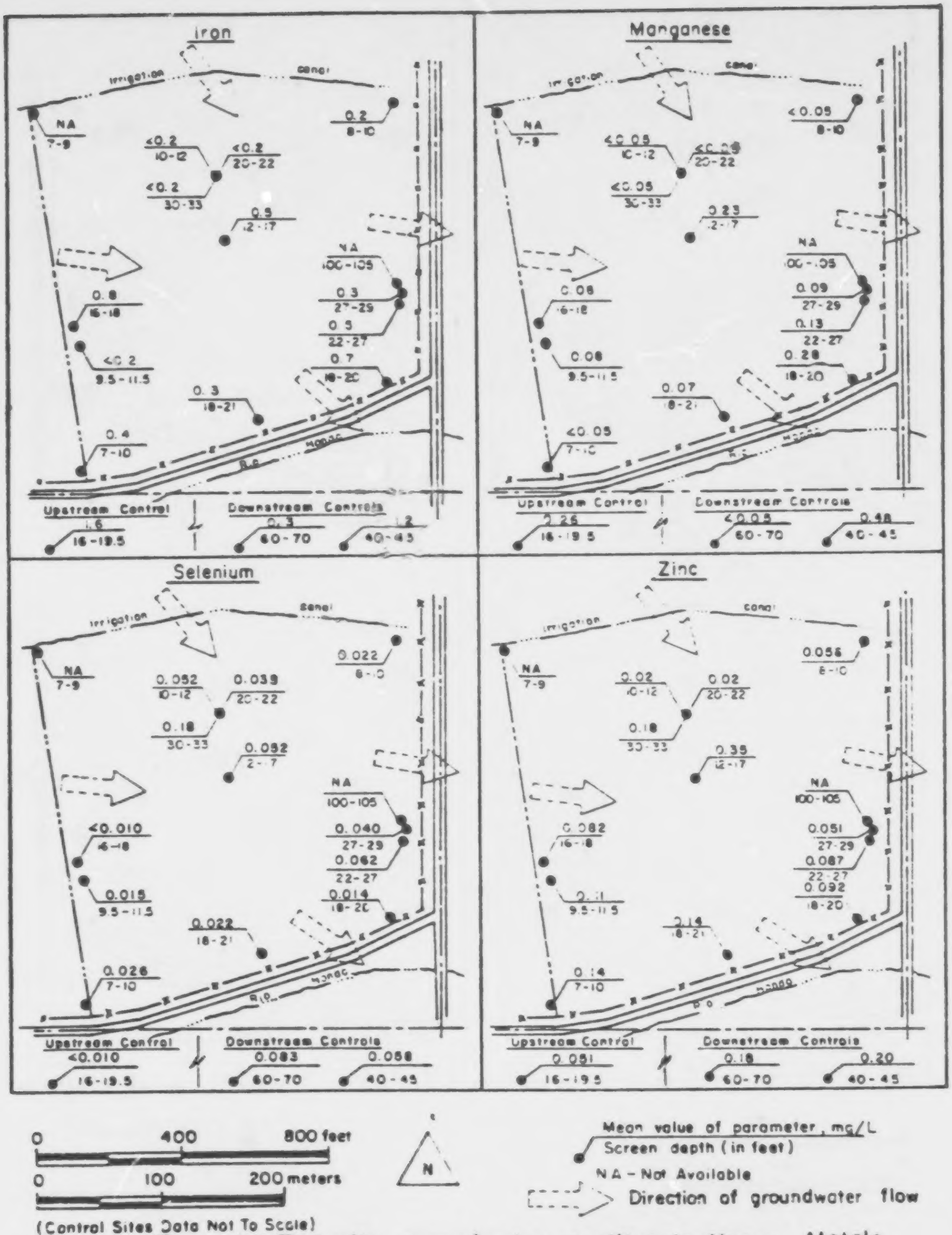
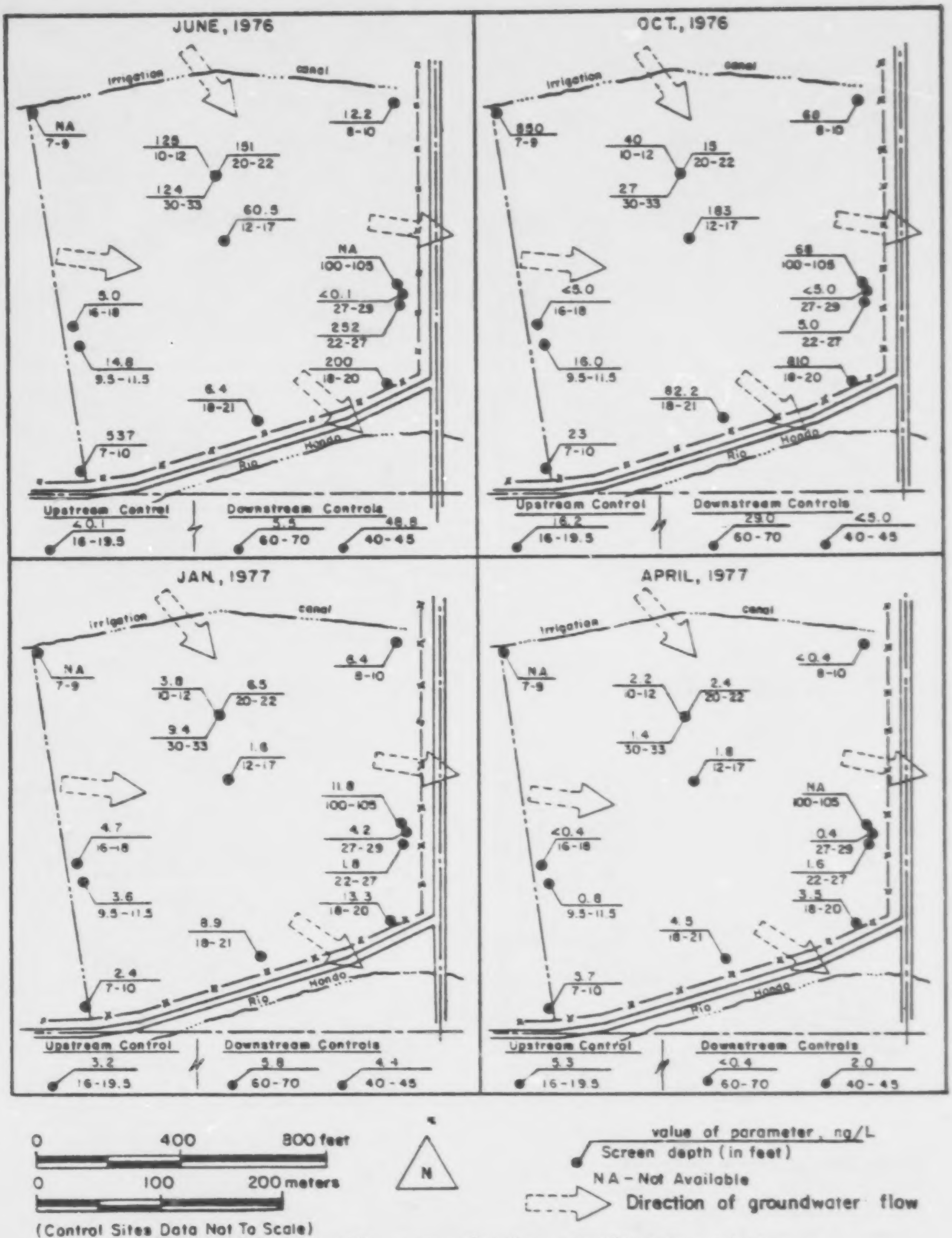


Figure 22. Test site groundwater constituents-Heavy Metals.



(Control Sites Data Not To Scale)

Figure 23. Test site groundwater constituents - Lindane.

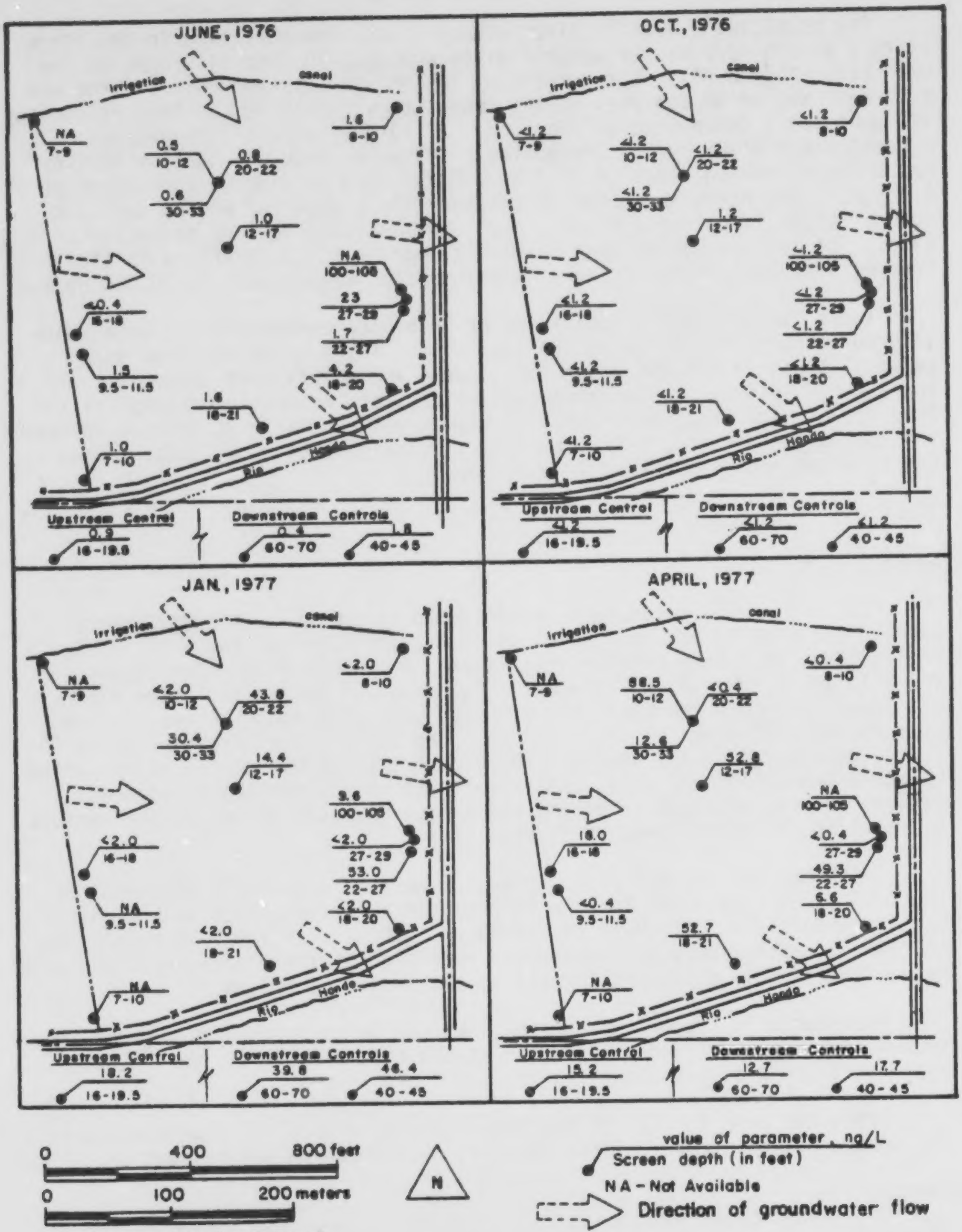


Figure 24 Test site groundwater constituents - 2,4-D

The herbicide 2,4,5 TP silvex occurred at a concentration in the range of <0.2 to 105 ng/L at the control sites and from <0.2 to 81.8 ng/L at the test site (Figure 25). The average of 12 analyses at the control sites was 21.7 ng/L and of 48 analyses at the test site was 25.8 ng/L. The irrigation effluent had a concentration range of <0.2 to 70.4 ng/L and an average concentration of 28 ng/L. Irrigation groundwater from the shallow aquifer had a concentration range of <0.2 to 5.8 ng/L and an average concentration of 2.1 ng/L. The difference between concentrations observed at the test and control sites is not significant, given the availability and variation in data. The maximum contaminant level allowed for 2,4,5 TP silvex in the current National Interim Primary Drinking Water Regulations is 10,000 ng/L.

There was no trend of pesticide or herbicide concentrations with depth of groundwater or location at the test site. There appeared to be some seasonal trend in concentration for lindane and a different seasonal trend for 2,4,5 TP silvex. Lindane concentrations were generally maximum for the June, 1976, sampling, while 2,4,5 TP silvex was generally at maximum concentration in the January, 1977, sampling. The significance of these trends is not apparent and is not readily explainable.

SOILS

General

For many of the parameters investigated in the soil, the difference between the control and test sites was not significant at the 0.05 level, particularly at depths greater than 10 cm. Mean values and statistical analysis are presented in Table 25. The method of pooled variances was utilized to compare the means for the test site with those of the control site at the 0.05 level of significance. The upper three sampling depths (0-10 cm) were combined for analysis because of tillage during the study period. Relative comparisons of total and extractable concentrations of elements between control and test sites and the normal expected ranges of the various elements in soils are shown in Figures 26 and 27.

Of the 38 soil parameters studied, 17 were significantly different at the 0.05 level (Table 25) for the 0-10 cm depth, while only 5 were significantly different for the 0-10 cm and 30 cm depths. For the 0-10 cm, 30 cm, and 100 cm depths, only two parameters were significantly different, and none were significantly different for all depths including 300 cm.

Phosphorus is the only parameter that can be correlated throughout the system as being significantly greater at the test site in irrigation water, upper soil profile, and plant leaves.

Since the past fertilizer and cropping history was the same for the test and control sites, these effects were not considered in the evaluation.

Phosphorus--

Total--The total phosphorus concentration of test and control sites was compared at six depths in order to estimate the phosphorus load as a result of irrigation with effluent (Table 26).

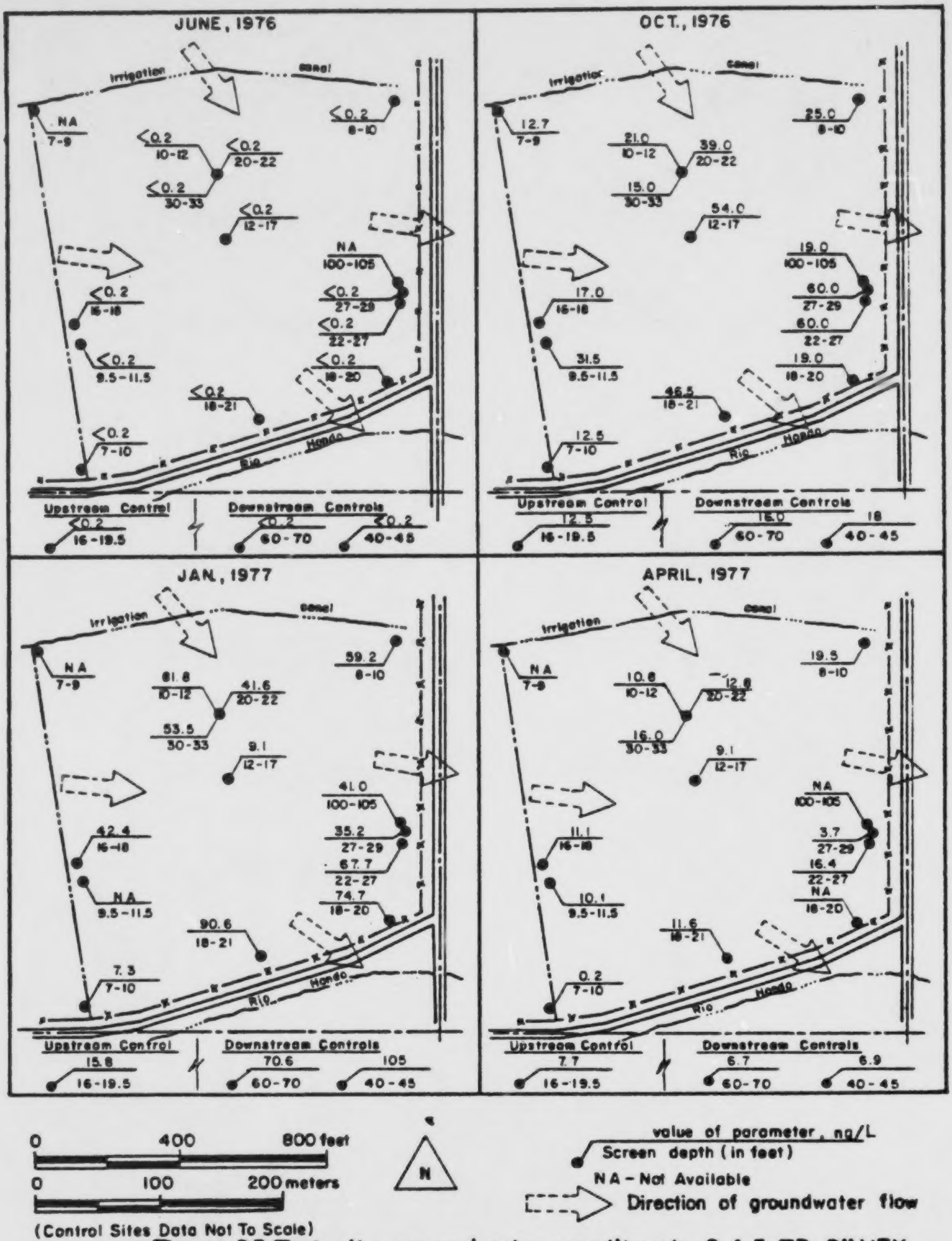


Figure 25.Test site groundwater constituents-2,4,5 TP SILVEX

TABLE 25. SOIL MEANS FROM THE TEST AND CONTROL SITES

	Means (µg/g except where noted)							
	Depth: 0-10 cm		Depth: 30 cm		Depth: 100 cm		Depth: 300 cm	
	Test	Control	Test	Control	Test	Control	Test	Control
pH	8.2	8.1	8.1	7.9	7.8	7.8	8.1	7.9
Inorganic Nitrogen	56.5[a]	32.5	56.0	32.9	27.2	23.7	30.5	29.4
Total Organic Nitrogen	1777[a]	1220	859	764	350	502	260	287
Total Phosphorus	1635[a]	1103	1174[a]	855	655	795	748	665
Available Phosphorus	56[a]	18	12	9	5	9	6	1
Total Sulfur	1930	3935	4100	8317	14607	21059	3252	15050
Cation Exchange Capacity (meq/100 g)	31[a]	26	30	26	32[a]	26	26	27
Extractable Aluminum	3.0[b]	3.0[b]	3.0[b]	3.0[b]	3.0[b]	3.0[b]	3.0[b]	3.0[b]
Extractable Boron	1.15[a]	0.65	1.14	0.75	0.92	0.68	0.89	0.68
Extractable Cadmium	0.05[b]	0.05[b]	0.05[b]	0.05[b]	0.05[b]	0.05[b]	0.05[b]	0.05[b]
Extractable Cobalt	0.12[b]	0.12[b]	0.12[b]	0.12[b]	0.12[b]	0.12[b]	0.12[b]	0.12[b]
Extractable Chromium	0.10[b]	0.10[b]	0.10[b]	0.10[b]	0.10[b]	0.10[b]	0.10[b]	0.10[b]
Extractable Copper	1.6[a]	1.0	2.3[a]	1.0	2.7	1.9	2.2	1.9
Extractable Iron	14[a]	9	11[a]	7	20[a]	7	20	14
Extractable Lead	2.6[a]	1.7	1.6	1.5	2.6	1.0	3.3	1.5
Exchangeable Magnesium (mg/g)	1.1[a]	0.9	1.1	0.9	1.22	1.23	1.07	1.35
Extractable Manganese	53	21	39	17	57	15	19	11
Extractable Nickel	0.5[a]	0.2	0.4[a]	0.2	0.4[a]	0.2	0.5	0.2
Exchangeable Potassium (mg/g)	1.1[a]	0.6	1.1	0.7	0.8	0.5	0.7	0.7
Exchangeable Sodium (mg/g)	1.5	1.2	1.4	1.2	2.0	1.7	2.3	2.5
Extractable Zinc	2.20[a]	0.93	1.61	0.98	0.88	1.08	1.10	0.73
Total Aluminum (mg/g)	22	21	24	22	20	15	25	17
Total Cadmium	5[b]	5[b]	5[b]	5[b]	1[b]	1[b]	1[b]	1[b]
Total Calcium (mg/g)	29	31	32	38	37	44	27[a]	51
Total Cobalt	10	9	9	7	8	8	12	10
Total Chromium	32[a]	28	32	28	30	26	31	24
Total Copper	19	18	19	19	17	20	20	18
Total Iron (mg/g)	27	24	25	27	31	22	37	30
Total Lead	10[b]	10[b]	10[b]	10[b]	5[b]	5[b]	5[b]	5[b]
Total Magnesium (mg/g)	5.4	6.1	5.4	7.1	5.6	6.3	4.0	5.6
Total Manganese	355[a]	410	346	428	266[a]	441	340	517
Total Mercury	0.5[b]	0.5[b]	0.5[b]	0.5[b]	0.5[b]	0.5[b]	0.5[b]	0.5[b]
Total Nickel	11.0	11.7	11.7	12.8	12.9	16.5	12.7	13.5
Total Potassium (mg/g)	11.3	12.9	11.1	11.4	11.1	12.7	11.2	9.4
Total Sodium (mg/g)	5.5[a]	6.6	5.0[a]	6.8	4.5	6.0	5.4	5.7
Total Zinc	70[a]	60	69	62	64	61	66	46
Total Arsenic	21	17	22	18	24[a]	11	26	25
Total Selenium	2	1[b]	1	1[b]	1	1[b]	1	1[b]

[a] Test and control sites significantly different at the 0.05 level.

[b] Concentrations below detection limit indicated.

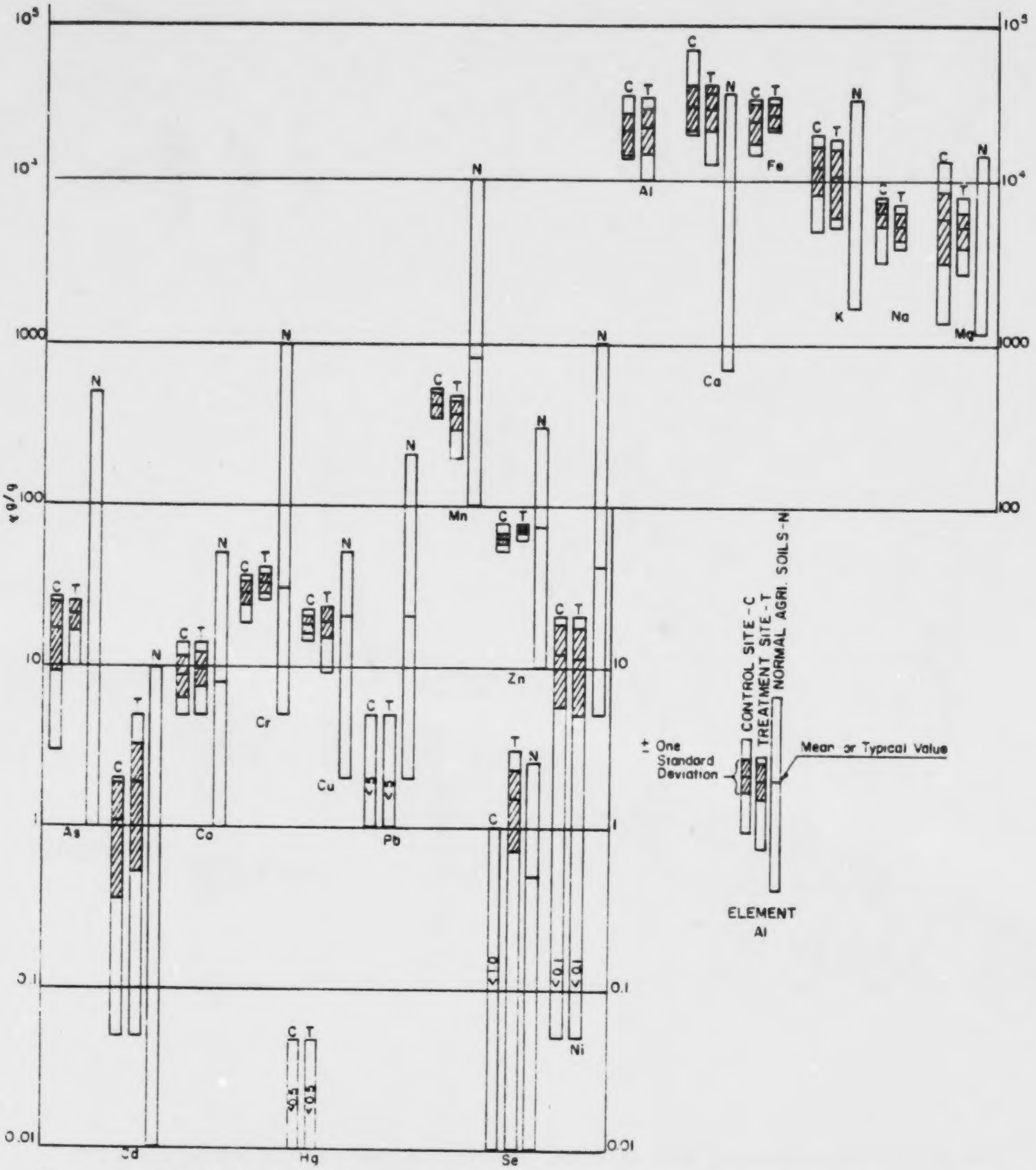


Figure 26. Total chemical element concentration levels for surface soils (0-10cm) in control site, test site, and normal agriculture soils.

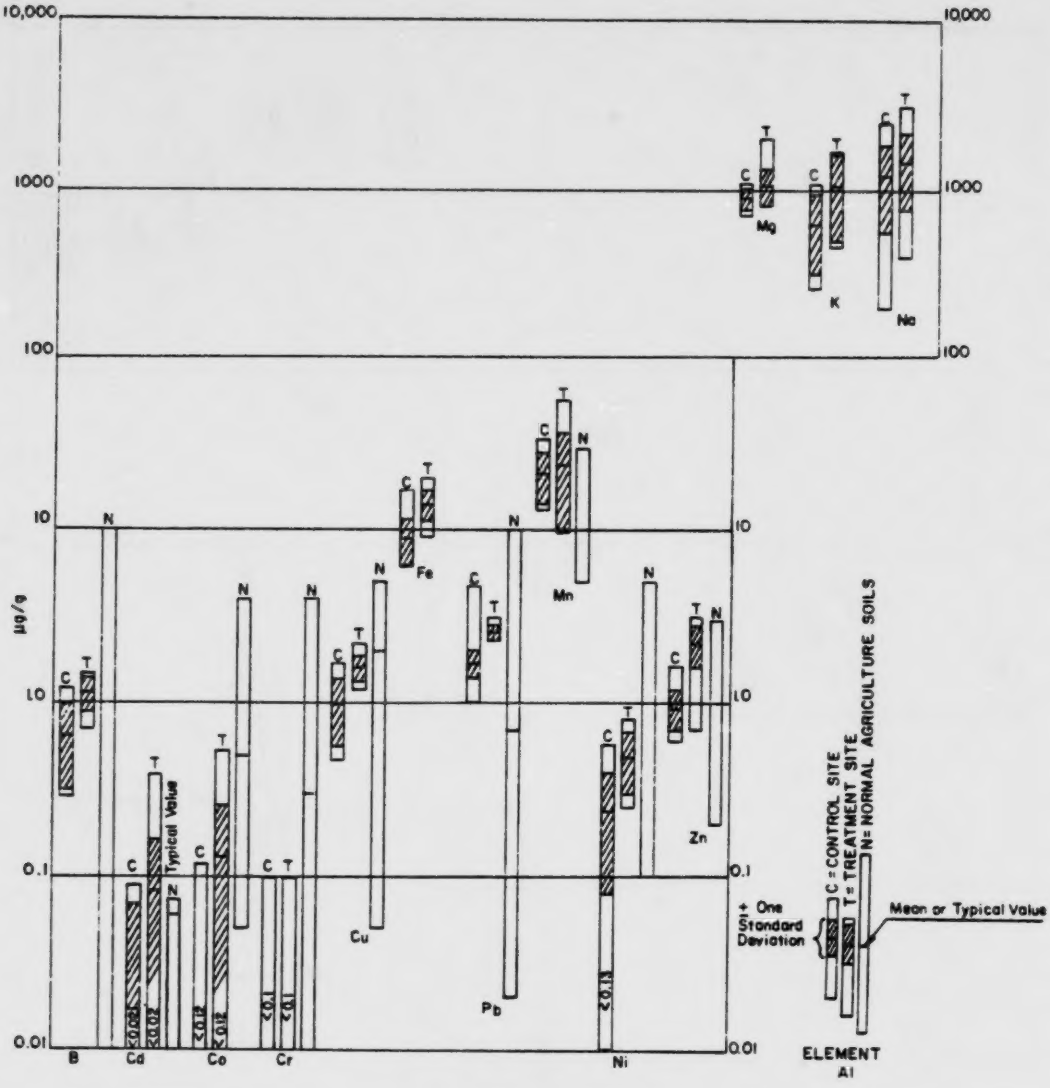


Figure 27. Extractable or exchangeable chemical element concentration levels for surface soils (0-10cm) in control site, test site, and normal agriculture soils.

TABLE 26. ACCUMULATION OF TOTAL PHOSPHORUS (P) IN THE SOIL

Depth = 1 cm		Depth = 3 cm		Depth = 10 cm		Depth = 30 cm		Depth = 100 cm		Depth = 300 cm	
Sample No.	P (μg/g)	Sample No.	P (μg/g)	Sample No.	P (μg/g)	Sample No.	P (μg/g)	Sample No.	P (μg/g)	Sample No.	P (μg/g)
Control Site											
11111	1524	11112	1092	11113	1114	11114	856	11115	737	11116	791
11211	1007	11212	985	11213	1201	11214	813	11215	877	11216	823
11311	1039	11312	953	11313	1093	11314	899	11315	1028	11316	597
11131	1215	11132	1106	11133	955	11134	916	11135	779	11136	882
11231	1145	11232	1141	11233	928	11234	894	11235	726	11236	866
11331	1284	11332	1084	11333	981	11334	752	11335	620	11336	528
$\bar{x}$ =	1202	$\bar{x}$ =	1060	$\bar{x}$ =	1045	$\bar{x}$ =	855	$\bar{x}$ =	795	$\bar{x}$ =	748
Test Site											
12111	1115	12112	1266	12113	1546	12114	1115	12115	446	12116	769
12211	1632	12212	1708	12213	1438	12214	1028	12215	759	12216	705
12311	1632	12312	1481	12313	1675	12314	1007	12315	662	12316	974
12131	2051	12132	1976	12133	1817	12134	1410	12135	869	12136	733
12231	1514	12232	1492	12233	1580	12234	1508	12235	671	12236	566
12331	1828	12332	1962	12333	1723	12334	978	12335	523	12336	741
$\bar{x}$ =	1629	$\bar{x}$ =	1648	$\bar{x}$ =	1630	$\bar{x}$ =	1174	$\bar{x}$ =	655	$\bar{x}$ =	748

$\bar{x}$ = Means.

The accumulation of phosphorus due to effluent irrigation was restricted to the upper 30 cm (12 in) of the soil profile.

The phosphorus content of the effluent was in the range of 5.2 to 9.5 mg/L with a mean value of 8 mg/L. At an application rate of 0.80 meter per year for 33 years, the total phosphorus applied to the test site was 2,110 kg/ha (1,880 lb/acre).

The analyses of the soil indicated an excess of total phosphorus at the test site over the control site in a range of 187 to 527 μg/g with a mean of 493 μg/g at depths of 0 to 10 cm (0 to 4 in) and a range of 226 to 616 μg/g with a mean of 452 μg/g at depths of 10 to 30 cm (4 to 12 in). At a bulk density of 1.3 and 1.5 for the 0 to 10 cm (0 to 4 in) depth and 10 to 30 cm (4 to 12 in) depth, respectively, calculations indicated a total excess of phosphorus in the upper 30 cm (12 in) of the test site soil of 1,997 kg/ha (1,780 lb/acre).

The variance between the calculation based on effluent analysis and that based on soil analysis is less than the variance in the data. Therefore, for practical purposes, the assumption was made that all the phosphorus added through irrigation with effluent can be accounted for by accumulation in the soil, since both sites had been fertilized equally.

Available--Available phosphorus, the more soluble form of phosphorus, was not significantly different below the 10-cm depth. The water-soluble orthophosphate, contained in the effluent at a mean value of 6.5 mg/L, is rendered insoluble as the effluent infiltrates the soil.

Exchangeable Potassium--

The exchangeable potassium in the test site soil is significantly greater than that in the control site soil at the 0-10 cm depth only. This correlates with the irrigation water analysis, since the potassium content of the effluent is significantly greater than that of the well water.

The mean potassium content of the corn leaves is the same. Since the total potassium content of the soil at both sites is practically the same, the assumption is made that luxury consumption of potassium occurred in the corn and masked the effect of the potassium in the wastewater.

Nitrogen--

The data for inorganic nitrogen and organic nitrogen for the soils are tabulated in Tables C-1 and C-2, Appendix C. The first step in the analysis was to compute various means to facilitate observation of trends. The following trends were observed:

Observation 1: Organic nitrogen concentration at the test site was greater than that at the control site for depths less than 10 cm. For depths greater than 10 cm, no difference was observed.

Observation 2: There was a consistent decrease of organic nitrogen with increased depth at the control and the test sites.

Observation 3: Inorganic nitrogen concentration at the test site was greater than that at the control site for depths less than 30 cm. For depths greater than 30 cm, no difference was observed.

Observation 4: There was a seasonal decrease in inorganic nitrogen from June, 1976, to January, 1977.

An analysis using statistical and regression techniques was applied to the data to validate the accuracy of the observations made above. The analysis is summarized in Appendix C.

Cation Exchange Capacity--

Although the values for cation exchange capacity were lower than expected for this soil type, there was a significant difference in the 0-10 cm depth. This correlates with the increased organic matter content based on the organic nitrogen content at that depth. Although no significant difference was apparent at the 30 cm depth, there was a significant difference in cation exchange capacity at the 100 cm depth, but this did not correlate with organic matter. This is considered an anomaly, since it is unlikely that organic matter has infiltrated to this depth in this soil type.

Other Significantly Different Soil Parameters--

Extractable boron, extractable lead, extractable zinc, exchangeable magnesium, total chromium, total selenium, and total zinc were significantly greater in the test site soil for the 0-10 cm depth only.

Extractable copper was significantly greater in the test site soil than in the control site soil at both the 0-10 cm depth and the 30 cm depth.

Extractable iron and nickel were significantly greater in the test site soil than in the control site soil at all depths down to and including 100 cm.

Although these parameters were not significantly different in the irrigation water, their means were greater in the effluent than in the well water. Considering the vast amount of irrigation water applied over the past 33 years, it is assumed that a real difference exists in minimal quantities that cannot be substantiated statistically with only one year's data.

The difference in iron content is assumed to be due to a natural difference in the two soils; this could possibly be true for copper and nickel as well, since they are not normally expected to leach to these depths if they are contained in effluent irrigation water.

Sodium and Manganese--

The total sodium and manganese content of the soil at the control site was significantly greater than that of the test site. This is assumed to be a natural occurrence since no difference exists between irrigation water.

All Other Parameters--

Those parameters not significantly different are considered to be equal at the same level of confidence.

PLANTS

The 21 parameters studied in the ear leaf of the corn plants at the test and control sites are shown in Table 27 with the differences computed at the 0.05 level of significance.

TABLE 27. MEAN CONCENTRATIONS OF PARAMETERS IN PLANT LEAVES FROM TEST AND CONTROL SITES

	Means (μg/g unless noted)		
	Test	Control	Normal Range[c]
Ammonium-N	647	335	--
Total Organic-N (mg/g)	19.5	14.2	27-35
Nitrite plus Nitrate-N	700	915	--
Total Phosphorus (mg/g)	3.4	2.3[a]	2-4
Total Sulfur	552	844	1000-3000
Arsenic	1	1[b]	1-10
Boron	28.0	32.6	10-100
Cadmium	2[b]	2[b]	0.01-1
Calcium (mg/g)	6.96	9.09[a]	4-10
Cobalt	5[b]	5[b]	1-50
Chromium	7	7	1-100
Copper	19	12	2-100
Lead	10[b]	10[b]	0.1-10
Magnesium (mg/g)	4.7	1.2	2-4
Manganese	77	49	5-500
Mercury	3[b]	3[b]	0.01-1
Nickel	5[b]	5[b]	1-100
Potassium (mg/g)	0.5	0.5	17-25
Sodium	108	75	100-500
Zinc	64	57	10-300
Selenium	0.5[b]	0.5[b]	0.1-10

[a] Significantly different at the 0.05 level.

[b] Concentration below detection limits indicated.

[c] Bear, 1964, and Walsh, 1973.

The phosphorus content of the test site corn leaves was significantly greater than that of the control site. It would appear that the crop nutrient quality was increased by the effluent irrigation.

The corn leaf's calcium content was significantly greater at the control site than at the test site with values at the high normal range. Although there was no significant difference in calcium values in the soil and water samples between the test and control site, the sample means for the control site calcium were slightly higher in all cases. This could account for the higher calcium of the control site plants.

All other parameters investigated in corn leaves are considered equal and are within normal ranges.

The 21 parameters analyzed in the corn grain from the test site are compared with normal values in Table 28. Data from the control site were not available due to a variation in harvesting methods that made it impossible to obtain a grain sample.

TABLE 28. MEAN CONCENTRATIONS OF PARAMETERS IN CORN GRAIN FROM TEST SITE AND NORMAL VALUES

	Means (μg/g unless noted)	
	Test	Normal Value
Ammonium-N	51	--
Total Organic-N (mg/g)	10.1	10
Nitrite plus Nitrate-N	781.5	--
Total Phosphorus (mg/g)	3.5	1.7
Total Sulfur	369.5	1500
Arsenic	<1	--
Boron	10.5	4.7
Cadmium	2	<0.5
Calcium (mg/g)	0.1	1.8
Cobalt	<5	0.1
Chromium	4	0.8
Copper	11	5
Lead	<10	0.8
Magnesium (mg/g)	0.4	1.2
Manganese	<10	6
Mercury	<3	--
Nickel	<5	<0.5
Potassium (mg/g)	0.5	4
Sodium	53.6	26.2
Zinc	26.3	10
Selenium	<0.5	0.4

The values for sulfur and calcium in the analyses of the corn grain were lower than are normally found. This was unexplainable since there were no control samples for comparison.

The data in Tables 27 and 28 indicate that no detrimental elements are entering the food chain due to wastewater irrigation of the corn crop.

HEALTH ASPECTS

Viruses

The sewage treatment plant effluent tested positive for viruses. Poliovirus types I, II, and III were found on all three testing dates, and Echovirus type 7 was present in the October, 1976, and April, 1977, runs but not in January, 1977 (Table 29).

TABLE 29. VIRUS IDENTIFICATION FROM SEWAGE TREATMENT PLANT EFFLUENT

Source Sample No.	Date Sampled	Infectious Virus Units Per 100 L Sample	Virus Identified[a]
STP Effluent 124602	10/23/76	125	Poliovirus I[b] Poliovirus II Echovirus 7
STP Effluent 124603	1/8/77	96	Poliovirus II
STP Effluent 124604	4/27/77	507	Echovirus 7 Poliovirus III

[a] A limited number of infectious virus units were selected at random for identification. No attempt to quantify the viral types was made.

[b] No attempt was made to differentiate wild or vaccine strains.

Cytotoxicity in the October 23, 1976, sample of sewage treatment plant effluent required retesting after centrifugation and filtration in the laboratory. Viruses were found in this sample after retesting.

All samples from the test and upstream control wells tested negative for viruses (Table 30). The experience in this study confirmed that of other investigations in that recovery of viruses is rare from groundwater even near the surface or at sites of wastewater application and wherever the soil contains sufficient clay particles and the application is intermittent.

No attempt was made to further type the poliovirus isolates as to wild or vaccine strains. However, contacts with the New Mexico State Health Department and the National Center for Disease Control revealed no reports of polio cases in New Mexico during the study period.

TABLE 30. VIRUS ISOLATION

Source[a] Sample No.	Depth Screened (m)	Date Sampled (Mo/Day/Yr)	Original Volume of Sample (L)	Volume[b] of Concentrate (mL)	Infectious Virus Units per 100 mL of concentrate	Infectious Virus Units per 100 L of sample
Upstream Well						
110302	4.9-6.1	10/21/76	310	66	0	0
110303		1/7/77	114	55	0	0
110304		4/25/77	151	31	0	0
Upstream Well						
122302	7.0-7.9	10/22/76	330	55	0	0
122303		1/7/77	170	24	0	0
122304		4/25/77	167	35	0	0
STP Effluent						
124602	N/A	10/23/76	80	176	57	125
124603		1/8/77	57	55	100	96
124604		4/27/77	76	220	175	507
Test Site Well						
122012	3-3.7	10/22/76	333	66	0	0
122013		1/7/77	151	33	0	0
122014		4/25/77	133	33	0	0
Test Site Well						
121402	5.5-6.1	10/23/76	288	88	0	0
121403		1/8/77	159	34	0	0
121404		4/26/77	167	44	0	0
Test Site Well						
120432	8.2-8.8	10/20/77	352	55	0	0
120433		1/8/77	170	20	0	0
120434		4/26/77	167	42	0	0
Test Site Well						
122032	9.1-10.1	10/21/76	344	55	0	0
122033		1/7/77	159	50	0	0
122034		4/25/77	132	28	0	0
Test Site Well						
120702	30.5-32	10/20/76	291	121	0	0
120703		1/8/77	159	25	0	0

[a] For location of wells see Figures 5, 7 and 9.

[b] Volume of concentrate includes 10% fetal calf serum.

Additionally, there were no reported cases or epidemics of exanthems aseptic meningitides or respiratory disease coinciding with the isolation of Echovirus type 7 from the sewage treatment plant effluent.

It was significant that neither the tissue nor the surface of the corn grown on the study site was found to be contaminated with viruses. These results corroborated previous observations that crops rarely incorporate human viruses into their tissues and if allowed to be exposed to drying and sunlight, rarely exhibit viruses on their surface.

Coliform Bacteria

Most samples that showed high total and fecal coliform counts were collected during first round sampling (Figures 28 and 29). Although initially chlorination of wells was used after construction, it was later decided that the drill hole and gravel pack material should be chlorinated during well construction. The elimination of high total and fecal coliform counts on almost all later round samples validated this procedure.

A few wells (11060, 12030, 12090, 12150, 12160, and 12210) had positive total and, in some cases, fecal coliform tests after first round sampling. The source of the total and fecal coliform bacteria was unknown, although it seemed reasonable to assume that some field or laboratory contamination was possible despite the precautions taken to avoid such an occurrence. Perhaps of more significance was the high number of samples that showed no positive total or fecal coliform bacteria counts, indicating the satisfactory performance level of the land treatment system. Further, the statistical analysis (Tables 12-21) presented earlier demonstrated there was no significant difference at the 0.05 level between the means for fecal coliform in the groundwater at the test site and those at the control site.

INTERACTIONS OF WATER, SOILS, AND PLANTS

Necessarily, each of the parameters in this study had to be isolated for data analysis and later interpretation. However, in addition to the significance attributable to individual components of an ecosystem, the interactions of the various components are also significant. The physical components of the system (i.e., geology, hydrology, topography, etc.) comprise the structural framework for the development of the soil and the later biological components (i.e., bacteria, plants, soil organisms, and other animals).

The application of wastewater to the land with inherent constituents of the water may be regarded as an energy input to the ecosystem, resulting not only in enhanced plant growth, but adding a potential for diversity in species composition of the biota. The resulting enriched and improved environment is often overlooked by those whose primary focus is the potential health hazards often associated with use of sewage effluent.

Chemicals in the wastewater interact with one another and with soil particles at the air-soil interface. Several processes may occur here simultaneously such as oxidation, nitrification, denitrification, evaporation, and adsorption. As the water percolates through the soil, the physical

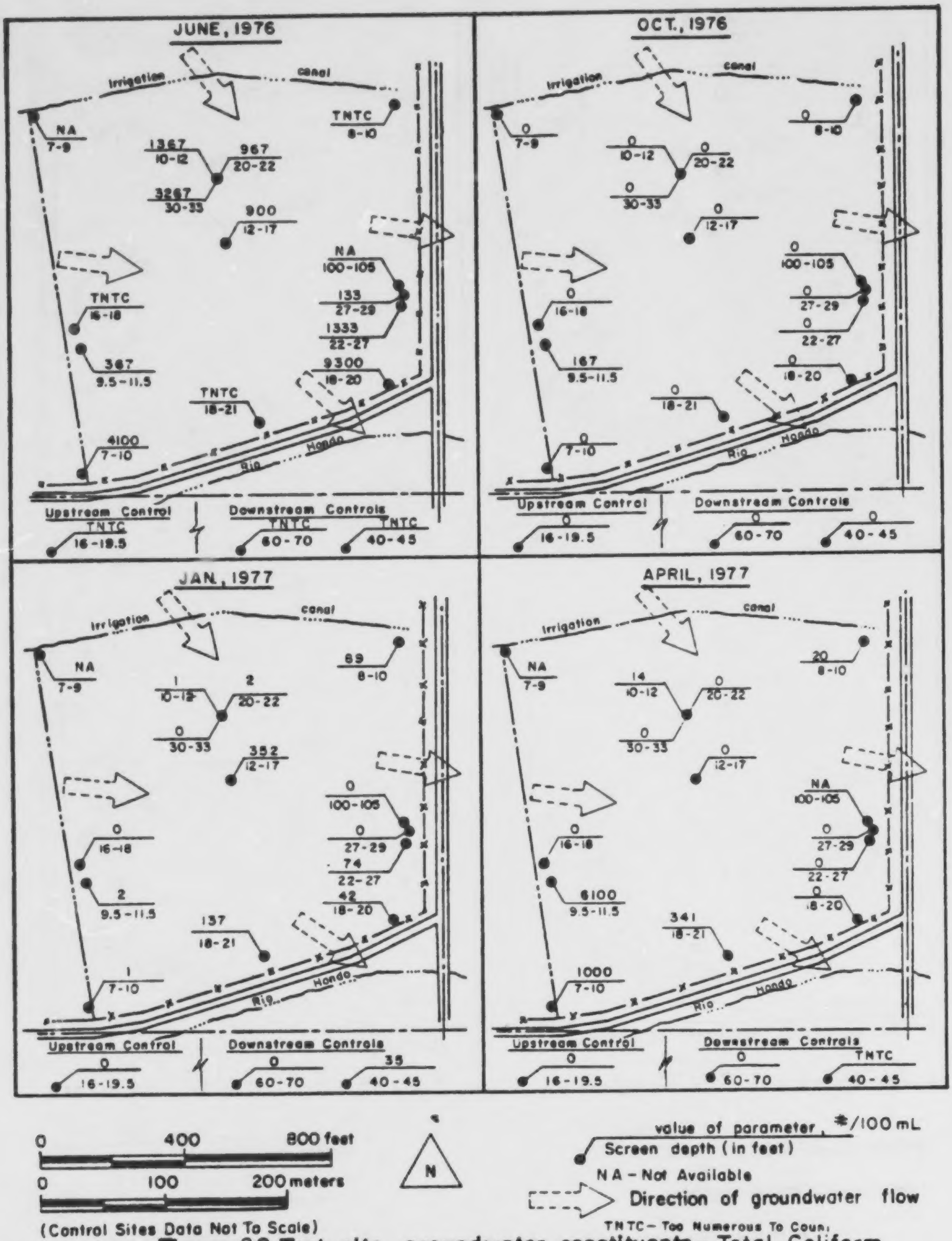


Figure 28 Test site groundwater constituents - Total Coliform

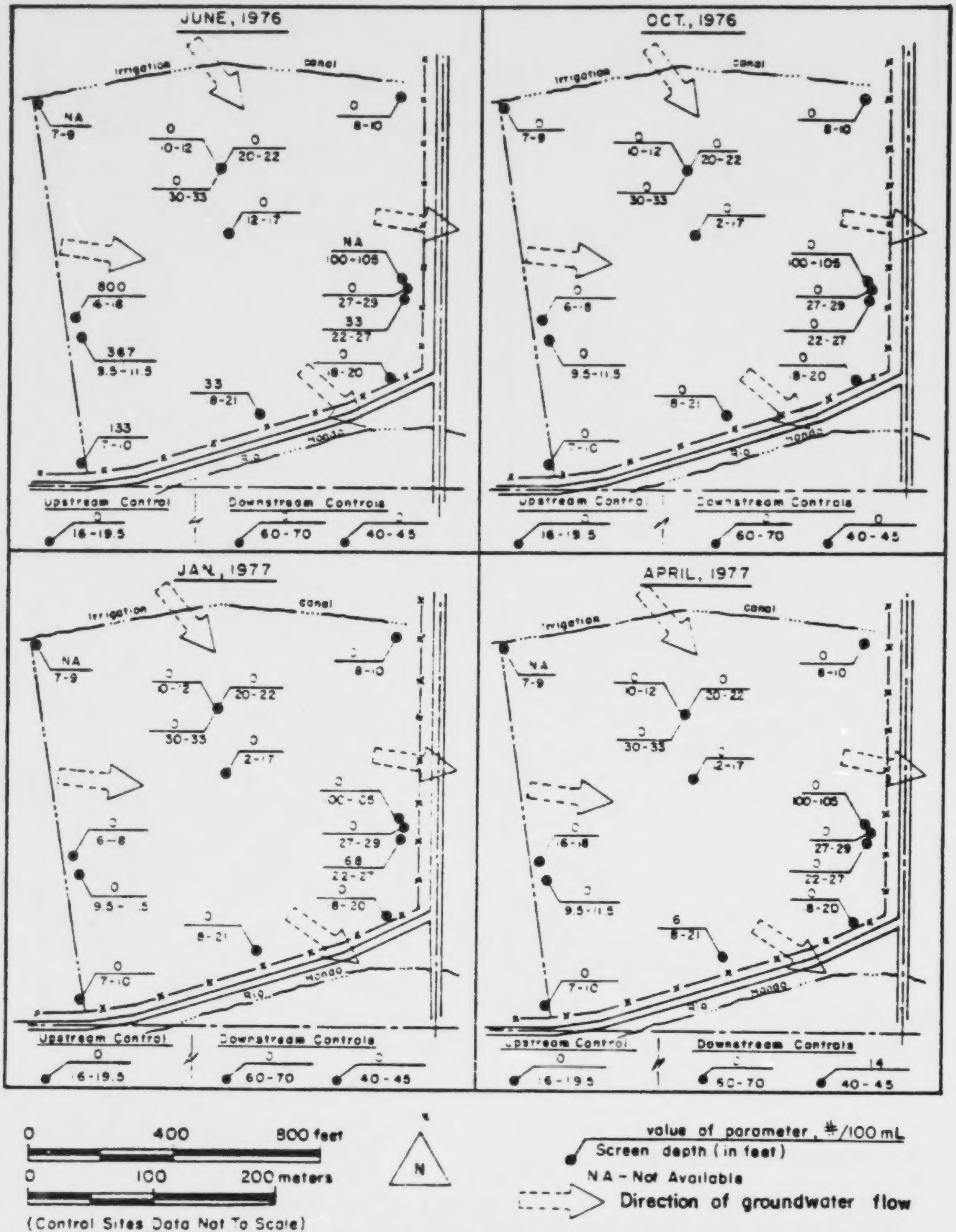


Figure 29. Test site groundwater constituents - Fecal Coliform

and chemical characteristics of the soil determine the fate of each element in its downward migration. Available surface area of soil particles and the chelating property of resident molecules combine to produce the distribution and abundance of the chemical species in the soil profile.

In a natural as well as an agricultural system, the results of the above interactions of soil and water influence the growth and development of plants. Major nutrients required for plant growth, such as nitrogen and phosphorus, as well as such trace elements as manganese or zinc are included as constituents in wastewater. For the proper design management of wastewater irrigated land, it is essential that these various interactions be taken into consideration. Mismanagement can result in a breakdown of natural processes and barriers that lead to crop failures, lower crop yields, or, more importantly, the appearance of toxic elements, viruses, or coliform organisms in groundwater. As indicated in several sections of this report, the land treatment system at Roswell has not experienced such negative occurrences.

PROJECTED USEFUL LIFE OF SITE FOR WASTEWATER IRRIGATION

The original intent of this study was to provide answers to a number of questions related to the long-term viability of land treatment systems. Two such questions discussed in the following paragraphs are:

1. For how long a period can a land treatment system be expected to provide satisfactory renovation treatment for wastewater?

2. What effect does continuing long-term application of organic, nitrogenous, and heavy metal constituents have on the soil and crop system?

If a projection of 100 years is considered, the additional load of phosphorus each year is 64 kg/ha (57 lb/acre) minus the harvest of 42 kg/ha (37 lb/acre) or 22 kg/ha (20 lb/acre); so the total prospective load is another 2,200 kg/ha (2,000 lb/acre). If all the phosphorus is eventually held as the stable hydroxyapatite, this will require 4,760 kg/ha (4,250 lb/acre) calcium or 11,900 kg/ha (10,625 lb/acre) calcium carbonate. If only half of the total calcium shown in the Roswell profile is calcium carbonate (a very conservative assumption), the reserve in the top 100 cm (39 in) of an acre is between 227,000 and 272,400 kg (500,000 and 600,000 lb), which is many times the required amount. The fact that no firm indication exists of any accumulation of phosphorus below 30 cm (12 in) is also reassuring; this plowed layer alone has proved to be a sufficient trap for the added phosphorus over 33 years.

The organic and inorganic nitrogen concentrations of the test site soils and the control site soils were compared to establish the respective additional loadings on the test site soils as a result of effluent irrigation. The additional organic nitrogen loading was calculated to be 1,400 kg/ha (1,200 lb/acre) down to a soil depth of 30 cm (12 in). The additional inorganic nitrogen loading was calculated to be 150 kg/ha (130 lb/acre) down to a soil depth of 300 cm (120 in). The 33-year projected application of nitrogen due to effluent application was in the range of 7,800 to 11,200 kg/ha (7,000 to 10,000 lb/acre) and due to synthetic fertilizer was 1,800 kg/ha (1,600 lb/acre). Cropping accounts for 7,400 kg/ha (6,600 lb/acre) and nitrate nitrogen recharge of the groundwater exiting the test site accounts for 400 kg/ha (360 lb/acre). Total nitrogen input was 9,600 to 13,000 kg/ha (8,600 to 11,600 lb/acre). Total nitrogen either at the test site or that has left the test site was 9,350 kg/ha (8,330 lb/acre). Unaccountable nitrogen, and therefore presumed to be expended to volatilization and denitrification, was 250 to 3,650 kg/ha (270 to 3,270 lb/acre). Comparisons between the zinc, copper, and chromium concentrations on the test site soils with those of the control site soils could not be reconciled with the effluent and groundwater concentrations of the respective metals.

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APPENDIX A

WELL LOGS FOR CONTROL AND TEST SITES

TABLE A-1. WELL LOG FOR CONTROL SITE

Hole 11010

Date: 6-21-76 Type Rig: Rotary
Casing: 2 in. plastic to 25.5 ft.
Screen: 2 in. slotted (0.030 in.) plastic 25.5 to 35.5 ft.
Remarks: Drilled with clear water, no sand pack, hole sealed with bentonite. Hole located at southwest end of abandoned airport, northwestern section of Roswell.

Log: Depth in Feet

0-2	Soil, silty, sandy, rocky
2-11	Sand, fine, silty and clayey
11-12	Limestone, hard, top of bedrock
12-14	Shale, dry
14-25.5	Dolomitic limestone, pink to light gray, hard
25.5-35	Sandstone, fine, silty and clayey
35-38	Dolomite, hard

Hole 11020

Date: 6-21-76 Type Rig: Rotary
Casing: None
Screen: None
Remarks: Hole located in creek bottom at southwest end of abandoned airport, hole backfilled and sealed with bentonite.

Log: Depth in Feet

0-1	Sand and gravel
1-6	Caliche and caliche cemented gravel
6-17	Dolomitic limestone, thin, interbedded with silty shale
17-29	Shale, silty, white
29-30	Dolomitic limestone
30-32	Shale, silty
32-35	Dolomite, red to pink, hard

Hole 11030

Date: 6-21-76 Type Rig: Rotary
Casing: 2 in. plastic to 16 ft.
Screen: 2 in. slotted (0.030 in.) plastic 16 to 19.5 ft.
Remarks: Drilled with clear water, no sand pack, sealed with bentonite. Upstream from study site.

Table A-1. Continued

Log: Depth in Feet

0-2	Soil
2-15	Clay, silty, tan to brown, darker near base
15-16	Sand, silty
16-21	Gravel and sand

Hole 11040

Date: 6-21-76 Type Rig: Rotary
Casing: 2 in. plastic to 20 ft.
Screen: 2 in. slotted (0.030 in.) plastic 20 to 24.5 ft.
Remarks: Drilled with clear water, no sand pack, sealed with bentonite. Upstream from study site.

Log: Depth in Feet

0-3	Soil, clayey
3-13	Clay, silty, sandy, brown
13-20	Sand, fine, silty
20-25	Gravel, sand, dirty, silty

Hole 11050

Date: 6-23-76 Type Rig: Rotary
Casing: 2 in. plastic to 60 ft.
Screen: 2 in. slotted (0.030 in.) plastic 60 to 70 ft.
Remarks: Drilled with clear water, no sand pack, sealed with bentonite. Downstream from study site, near Pecos River.

Log: Depth in Feet

0-2	Soil, silty and sandy
2-6	Clay, gray, silty
6-10	Sand, silty
10-13	Clay, silty
13-16	Sand, fine, silty
16-19	Sand, silty, with black organic mud streaks
19-29	Sand, fine, silty
29-35	Clay, white, soft
35-37	Sand, with green clayey sand streaks
37-43	Sand, fine to medium, reddish, several gravel streaks
43-48	Sand, with soft red clay lenses
48-70	Sand, medium to coarse, with red clay lenses, yellow sand at 65 ft.
70	Clay, gray

Table A-1. Continued

Hole 11060

Date: 6-23-76 Type Rig: Rotary
Casing: 2 in. plastic to 40 ft.
Screen: 2 in. slotted (0.030 in.) plastic 40 to 45 ft.
Remarks: Drilled with clear water, no sand pack, sealed with bentonite. Downstream from study site, near Pecos River

Log: Depth in Feet

0-1	Sand, fine
1-6	Sand, clayey, reddish brown
6-12	Sand, silty, fine
12-25	Sand, fine, gray, with lenses of soft clayey sand, lenses of black clay near base
25-35	Sand, very fine
35-39	Clay, white
39-45	Gravel and sand
45	Clay, gray

TABLE A-2. WELL LOG FOR TEST SITE

Hole 12010

Date: 6-11-76 Type Rig: Rotary
Casing: None
Screen: None
Remarks: Started drilling with clear water, lost circulation and stuck at 10 ft. Mixed 100 lbs. bentonite. Hole backfilled and sealed with bentonite.

Log: Depth in Feet

0-7	Soil, dark, clayey
7-11	Gravel, coarse, well rounded, with coarse sand
11-21	Sand, fine to medium with gravel

Hole 12020

Date: 6-11-76 Type Rig: Rotary
Casing: None
Screen: None
Remarks: Started drilling with clear water, drilled to 25 feet put in 25 feet of 6 in. plastic casing to hold hole open and continued drilling with 3 3/4 in. bit. Lost circulation at 27 feet mixed 100 lbs. bentonite and one sack bran. Hole backfilled and sealed with bentonite.

Log: Depth in Feet

0-12	Soil, silty, clayey, black to dark gray
12-16	Sand, fine, silty, with caliche fragments
16-30	Sand and gravel, 1/2 to 3/4 in. gravel
30-43	Sand, fine, with caliche cemented layers

Hole 12020a

Date: 6-12-76 Type Rig: Rotary
Casing: None
Screen: None
Remarks: Drilled with bentonite mud (200 lbs.), hole backfilled and sealed with bentonite.

Log: Depth in feet

0-14	Soil, silty with fine sand, dark and clayey
14-20	Sand, fine to medium, caliche grains
20-28	Gravel, with fine to medium sand, and red-brown clay lenses
28-30	Clay, brown
30-31	Gravel lenses and yellow clay layers
31-39	Gravel lenses and white clay layers

Table A-2. Continued

39-49	Clay, reddish, with white clay lenses, and hard silty sand layers
49-60	Clay, red
60-68	Clay, gray to white
68-69	Gravel
69-85	Clay, and clayey sand, red
85-106	Sand, very fine, silty and easy drilling
106-108	Clay, red
108-131	Sand, very fine, silty
131-150	Gravel, silty and clayey
150-164	Sand and gravel

Hole 12030

Date: 6-13-76 Type Rig: Rotary
Casing: 2 in. plastic to 22 ft.
Screen: 2 in. slotted (0.030 in.) plastic 22 to 27 ft.
Remarks: Drilled with clear water, sand pack 20 to 29 ft., hole sealed with granular bentonite.

Log: Depth in Feet

0-13	Soil, clayey, silty, dark gray to gray, light gray at base
13-25	Sand, fine, silty, with clay lenses
25-29	Gravel, sand, red clay lenses at top

Hole 12040

Date: 6-13-76 Type Rig: Rotary
6-17-76 Cable Tool

Casing: Multiple completion in 10 in. cable tool hole
2 in. plastic to 11 ft.
2 in. plastic to 20 ft.
2 in. plastic to 29 ft.
Screen: 2 in. slotted (0.030 in.) plastic 11 to 13 ft.
2 in. slotted (0.030 in.) plastic 20-22 ft.
2 in. slotted (0.030 in.) plastic 27-29 ft.

Remarks: Drilled rotary hole with clear water, redrilled with cable tool for multiple completion, sand pack 25 to 29 ft., granular bentonite 24 to 25 ft., sand pack 17 to 24 ft., bentonite 16 to 17 ft., sand pack 9 to 16 ft., top sealed with bentonite.

Log: Depth in Feet

0-19	Soil and silty sand, dark gray, light gray at base
19-25	Sand, fine, silty, with clay lenses
25-32	Gravel and sand, with clayey streaks
32	Clay

Table A-2. Continued

Hole 12050

Date: 6-13-76 Type Rig: Rotary
Casing: 2 in. plastic to 12 ft.
Screen: 2 in. slotted (0.030 in.) plastic 12 to 17 ft.
Remarks: Drilled with clear water, sand pack 11 to 17 ft., sealed with bentonite.

Log: Depth in Feet

0-6	Soil, dark gray, light gray at base
6-10	Sand, fine, silty, tan
10-13	Gravel, sand, coarse, silty, yellow color
13-23	Sand, fine, yellow

Hole 12060

Date: 6-13-76 Type Rig: Rotary
Casing: 2 in. plastic to 6 ft.
Screen: 2 in. slotted (0.030 in.) plastic 6 to 11 ft.
Remarks: Drilled with clear water, sand pack 5 to 11 ft., sealed with bentonite.

Log: Depth in Feet

0-5	Soil, dark, silty, clayey
5-14	Sand and gravel, clayey, silty, sand, fine to medium

Hole 12070

Date: 6-14&15-76 Type Rig: Rotary
Casing: 2 in. plastic to 100 ft.
Screen: 2 in. slotted (0.030 in.) plastic 100 to 105 ft.
Remarks: Drilled with heavy bentonite mud (550 lbs.) to get through shallow gravel zone, flushed hole, drilled with clear water below 95 ft., sand pack 95 to 105 ft., sealed with bentonite.

Log: Depth in Feet

0-15	Soil, clayey, silty, dark gray, light gray at base
15-24	Sand, fine, yellow, lot of fossil hash
24-30	Gravel, sand, silty
30-40	Sand, fine, silty, brown
40-47	Sand, fine, clayey, reddish
47-68	Sand, very fine, clayey, gray to reddish brown
68-75	Clay, red, silty
75-90	Sand, fine, silty, lenses of clay
90-115	Sand, fine to medium

Table A-2. Continued

Hole 12080

Date: 6-15-76 Type Rig: Rotary
Casing: 6 in. plastic to 19 ft.
Screen: 6 in. slotted (0.030 in.) plastic 19 to 29 ft.
Remarks: Drilled with clear water, no sand pack, water-level recorder well, sealed with bentonite.

Log: Depth in Feet

0-6	Soil, clayey, dark gray
6-20	Sand, fine, silty and clayey
20-23	Gravel, sand, silty
23-31	Sand, fine to medium, silty at base

Hole 12090

Date: 6-15-76 Type Rig: Cable Tool
Casing: 2 in. plastic to 16 ft.
Screen: 2 in. slotted (0.030 in.) plastic 16 to 18 ft.
Remarks: Trouble with caving even with cable tool, sand pack 14 to 23 ft., hole sealed with bentonite.

Log: Depth in Feet

0-10	Soil, clayey
10-18	Gravel, sand
18-27	Clay, with scattered gravel and sand

Hole 12100

Date: 6-15-76 Type Rig: Rotary
Casing: 2 in. plastic to 23 ft.
Screen: 2 in. slotted (0.030 in.) plastic 23 to 33 ft.
Remarks: Drilled with bentonite mud, no sand pack, sealed with bentonite.

Log: Depth in Feet

0-5	Soil, clayey, dark gray
5-19	Sand, fine, silty and clayey
19-21	Sand, fine to medium
21-27	Gravel and sand
27-33	Sand, fine to medium

Table A-2. Continued

Hole 12111

Date: 6-16-76 Type Rig: Rotary
Casing: 2 in. plastic to 21 ft.
Screen: 2 in. slotted (0.030 in.) plastic 21 to 31 ft.
Remarks: Drilled with bentonite mud, no sand pack, sealed with bentonite.

Log: Depth in Feet

0-5	Soil, clayey, dark
5-22	Sand, fine, silty and clayey
22-26	Gravel, sand, fine to medium, silty
26-31	Sand, fine to medium

Hole 12120

Date: 6-16-76 Type Rig: Rotary
Casing: 2 in. plastic to 18 ft.
Screen: 2 in. slotted (0.030 in.) plastic 18 to 28 ft.
Remarks: Drilled with bentonite mud, no sand pack, sealed with bentonite.

Log: Depth in Feet

0-5	Soil, clayey, dark
5-16	Sand, fine, silty and clayey
16-20	Gravel, sand, fine to coarse, sand yellow
20-21	Clay, yellow, sandy
21-25	Sand, fine to coarse
25-26	Gravel, sandy
26-27	Sand, fine
27-28	Clay, red

Hole 12130

Date: 6-16-76 Type Rig: Rotary
Casing: 2 in. plastic to 8 ft.
Screen: 2 in. slotted (0.030 in.) plastic 8 to 10 ft.
Remarks: Drilled with clear water, no sand pack, sealed with bentonite.

Log: Depth in Feet

0-5	Soil, clayey and silty, dark
5-13	Gravel and sand, fine to medium

Table A-2. Continued

Hole 12140

Date: 6-16-76 Type Rig: Rotary
Casing: 2 in. plastic to 18 ft.
Screen: 2 in. slotted (0.030 in.) plastic 18 to 20 ft.
Remarks: Drilled with clear water, sand pack 17 to 20 ft., sealed with bentonite.

Log: Depth in Feet

0-14	Soil, clayey, silty with sand, dark
14-20	Sand, fine to medium, caliche grains
20	Gravel

Hole 12150

Date: 6-16-76 Type Rig: Rotary
Casing: 2 in. plastic to 8 ft.
Screen: 2 in. slotted (0.030 in.) plastic 8 to 10 ft.
Remarks: Drilled with clear water, sand pack 7 to 10 ft., sealed with bentonite.

Log: Depth in Feet

0-6	Soil, clayey, dark
6-7	Clay, yellow
7-10	Sand, medium, silty, with gravel

Hole 12160

Date: 6-16-76 Type Rig: Rotary
Casing: 2 in. plastic to 18 ft.
Screen: 2 in. slotted (0.030 in.) plastic 18 to 21 ft.
Remarks: Drilled with clear water, sand pack 17 to 21 ft., sealed with bentonite.

Log: Depth in Feet

0-13	Soil, clayey, dark
13-16	Clay, black, organic, soft, with scattered gravel
16-21	Gravel, sand, medium

Hole 12170

Date: 6-18-76 Type Rig: Rotary
Casing: 2 in. plastic to 7 ft.
Screen: 2 in. slotted (0.030 in.) plastic 7 to 9 ft.
Remarks: Drilled with clear water, sand pack 6 to 9 ft., sealed with bentonite.

Table A-2. Continued

Log: Depth in Feet

0-5	Soil, clayey, light brown, carbonate in clay
5-7	Sand, fine to medium
7-12	Gravel and sand

Hole 12180

Date: 6-17-76 Type Rig: Rotary
Casing: None
Screen: None
Remarks: Drilled with bentonite mud, 10 ft. north of No. 1209, hole caved badly and finally backfilled and sealed with bentonite.

Log: Depth in Feet

0-4	Soil, clayey, dark
4-9	Sand, fine, silty, clayey
9-13	Gravel, sand, medium

Hole 12190

Date: 6-18-76 Type Rig: Rotary
Casing: None
Screen: None
Remarks: Drilled with bentonite mud, 30 ft. south of No. 1209, abandoned, backfilled and sealed with bentonite.

Log: Depth in Feet

0-7	Soil, clayey, dark
7-10	Gravel and sand
10-11	Clay, sandy, soft, pink
11-19	Gravel and sand
19-44	Sand, fine, silty and clayey

Hole 12200

Date: 6-18-76 Type Rig: Cable Tool
Casing: Multiple completion in 10 in. cable tool hole
2 in. plastic to 10 ft.
2 in. plastic to 20 ft.
2 in. plastic to 30 ft.
Screen: 2 in. slotted (0.030 in.) plastic 10 to 12 ft.
2 in. slotted (0.030 in.) plastic 20 to 22 ft.
2 in. slotted (0.030 in.) plastic 30 to 33 ft.

Table A-2. Continued

Remarks: Cable tool hole, sand pack 26 to 33 ft., bentonite seal 25 to 26 ft., sand pack 15 to 25 ft., bentonite seal 14 to 15 ft., sand pack 7 to 14 ft., bentonite seal at top of hole.

Log: Depth in Feet

0-9	Soil, clayey, dark
9-20	Sand, coarse with gravel
20-35	Sand, medium to coarse, silty

Hole 12210

Date: 6-18-76 Type Rig: Rotary
Casing: 2 in. plastic to 9.5 ft.
Screen: 2 in. slotted (0.030 in.) plastic 9.5 to 11.5 ft.
Remarks: Drilled with clear water, no sand pack, sealed with bentonite.

Log: Depth in Feet

0-7	Soil, silty and clayey, dark
7-11.5	Gravel, sand, medium to coarse

Hole 12220

Date: 6-18-76 Type Rig: Rotary
Casing: 2 in. plastic to 13 ft.
Screen: 2 in. slotted (0.030 in.) plastic 13 to 19 ft.
Remarks: Drilled with clear water, sand pack 12 to 19 ft., sealed with bentonite.

Log: Depth in Feet

0-2	Soil, rocky and sandy
2-9	Sand, silty
9-14	Clay, sandy, silty, brown to tan
14-15	Gravel lense, sandy
15-20	Sand, fine to medium
20-28	Gravel and sand

Hole 12230

Date: 6-19-76 Type Rig: Rotary
Casing: 2 in. plastic to 23.5 ft.
Screen: 2 in. slotted (0.030 in.) plastic 23.5 to 26 ft.
Remarks: Drilled with clear water, sand pack 23 to 26 ft., sealed with bentonite.

Table A-2.Continued

Log: Depth in Feet

0-3	Soil, silty and sandy
3-5	Sand, fine
5-23	Sand, clayey, silty
23-26	Gravel and sand
26-28	Sand, fine

Hole 12240

Date: 6-19-76 Type Rig: Rotary
Casing: 2 in. plastic to 21 ft.
Screen: 2 in. slotted (0.030 in.) plastic 21 to 24 ft.
Remarks: Drilled with clear water, sand pack 20 to 24 ft., sealed with bentonite.

Log: Depth in Feet

0-2	Soil, silty and sandy
2-5	Sand, fine
5-15	Clay, sandy, silty, yellow-brown
15-21	Sand, fine
21-25	Gravel and sand
25-28	Sand, fine

APPENDIX B

DATA TABLES FOR ALL WATER, SOIL, AND PLANT SAMPLES

LEGEND

Sample code numbers are explained in Section 7, "Results and Discussion."

99.9 means too numerous to count.

Negative sign (-) means less than.

Values in μg/g x 10^{-4} = percentage.

TABLE B-1. WATER DATA

SAMPLE NUMBER	COLLECTION DATE	DEPTH M	TEMP DEG C	DISSOLVED OXYGEN MG/L	PH	CONDUC-TIVITY UMHOS/CM	TOTAL ALKALINITY MG/L CACO3	DISSOLVED SOLIDS MG/L	SUSPENDED SOLIDS MG/L	TOTAL SOLIDS MG/L	VOLATILE SUSPENDED SOLIDS MG/L	BOD MG/L	COD MG/L	CL MG/L
116002	10/21/76			6.0	7.5	2260	168	1460				2	4	261
116003	1/ 5/77			6.3	7.6	2320	168	1483				-1	6	324
116004	4/27/77			1.9	7.0	1958	172	1386	233	1619	2	-1	11	282
114502	4/14/77							129	2223	2352			79	
114601	6/24/76			7.7	7.3	3600	184	3027				-1	24	889
114604	4/28/77			7.6	7.7	3597	168	2699	28	2727	5	2	19	933
114701	6/24/76			7.3	7.4	2600	196	2374				-1	44	710
110301	6/26/76	4.9	18.5	1.2	7.0	4100	356	4250				-1	64	710
110302	10/21/76	4.9		0.8	7.2	4872	260	3729				-1	20	620
110303	1/ 5/77	4.9		1.9	7.3	4900	272	3838				-1	88	673
110304	4/28/77	4.9	19.0	0.9	7.2	4180	300	4045				-1	41	716
110601	6/26/76	12.2	19.0	1.0	7.4	4620	220	3868				-1	12	1300
110602	10/22/76	12.2		1.8	7.5	6380	184	3733				-1	28	1170
110603	1/ 5/77	12.2		0.7	7.3	5470	184	3718				-1	30	1510
110604	4/28/77	12.2	19.0	2.6	7.5	8393	242	6729				1	14	2528
110501	6/26/76	18.3	19.0	1.2	7.0	11200	272	8278				-1	60	2840
110502	10/22/76	18.3		1.9	7.3	14690	216	9843				-1	111	3733
110503	1/ 5/77	18.3		1.7	7.3	13340	224					-1	87	4404
110504	4/28/77	18.3	18.0	2.1	7.4	9990	216	8578				1	14	2625
124601	6/23/76		24.5	1.6	7.6	2700	324	2504	18	2522		19	176	781
124602	10/21/76			0.5	7.6	3690	316	2074	74	2148		122	206	577
124603	1/ 6/77			6.1	7.5	3430	316	2193			10	6	135	820
124604	4/28/77			-0.1	7.6	2860	336	2008	32	2041	26	23	171	545
122011	6/23/76	3.0	15.0	1.2	6.8	8300	372	6749				-1	100	2059
122012	10/19/76	3.0		1.5	6.9	9020	304	6222				1	88	1931

TABLE B-1. Continued

SAMPLE NUMBER	COLLECTION DATE	DEPTH M	TEMP DEG C	DISSOLVED OXYGEN MG/L	PH	CONDUC- TIVITY UMHOS/CM	TOTAL ALKALINITY MG/L CACO3	DISSOLVED SOLIDS MG/L	SUSPENDED SOLIDS MG/L	TOTAL SOLIDS MG/L	VOLATILE SUSPENDED SOLIDS MG/L	BOD MG/L	COD MG/L	CL MG/L
122013	1/ 4/77	3.0		3.8	7.9	9230	324	6517				-1	60	2445
122014	4/27/77	3.0	13.5	2.2	7.0	9520	324	7904				3	24	2736
122021	6/23/76	6.1	14.5	1.4	6.8	8200	372	6728				-1	64	2059
122022	10/19/76	6.1		2.5	6.8	8260	280	5564				1	72	1652
122023	1/ 4/77	6.1		3.0	6.8	8132	288	5819				-1	54	2160
122024	4/27/77	6.1	14.0	2.9	6.9	8850	308	7341				1	20	2430
122031	6/23/76	9.1		4.6	6.9	7600	372	6457				-1	76	1846
122032	10/19/76	9.1		1.2	7.0	8249	304	5536				-1	68	1666
122033	1/ 4/77	9.1		2.5	7.9	7980	288	4244				-1	42	1032
122034	4/27/77	9.1	15.0	1.4	7.0	8496	312	7240				2	17	2392
120501	6/23/76	3.7	18.0	1.4	7.0	10000	472	8218				1	76	2130
120502	10/19/76	3.7		3.2	6.9	10502	356	7128				1	88	1999
120503	1/ 6/77	3.7		1.2	7.0	9440	356	6883				1	24	2570
120504	4/27/77	3.7	19.0	1.9	7.2	10388	460	9230				2	20	2625
120301	6/25/76	6.7	17.0	1.2	6.7	9000	324	7425				1	153	2090
120302	10/19/76	6.7		1.5	7.3	10440	304	7589				1	76	2339
120303	1/ 6/77	6.7		1.0	7.1	9050	268	6816				1	30	2223
120304	4/26/77	6.7	16.0	3.0	7.2	8618	318	7397				-1	36	2167
120431	6/24/76	8.2	16.5	1.5	6.7	9700	348	7907				-1	97	2130
120432	10/20/76	8.2		1.6	7.0	10620	300	7617				-1	76	2118
120433	1/ 4/77	8.2		1.2	7.1	8660	292	6546				-1	54	2134
120434	4/26/77	8.2	15.0	2.7	7.0	8624	332	7475				2	16	2170
122101	6/24/76	2.7	17.5	1.7	6.8	6300	332	5238				-1	48	1349
122102	10/21/76	2.7		1.4	6.9	6820	316	4798				1	16	1119
122103	1/ 5/77	2.7		2.2	7.1	7180	348	5437				-1	27	1715

TABLE B-1. Continued

SAMPLE NUMBER	COLLECTION DATE	DEPTH M	TEMP DEG C	DISSOLVED OXYGEN MG/L	PH	CONDUC-TIVITY UMHOS/CM	TOTAL ALKALINITY MG/L CACO3	DISSOLVED SOLIDS MG/L	SUSPENDED SOLIDS MG/L	TOTAL SOLIDS MG/L	VOLATILE SUSPENDED SOLIDS MG/L	BOD MG/L	COD MG/L	CL MG/L
122104	4/26/77	2.7	14.0	0.7	7.1	5074	352	4383				1	20	1020
120901	6/24/76	4.9	17.5	3.3	7.1	4200	324	4517				-1	52	1136
120902	10/21/76	4.9		0.9	7.2	6102	304	4032				1	12	986
120903	1/ 5/77	4.9		1.5	7.1	7360	320	5420				-1	40	1852
120904	4/26/77	4.9	15.0	0.5	7.2	4329	324	3537				-1	21	841
121702	10/21/76	2.1		2.5	7.8	7480	280	5081				3	60	1330
121601	6/24/76	5.5	17.5	2.3	6.9	7100	312	5570				-1	169	1525
121602	10/19/76	5.5		1.0	7.0	8496	368	5983				-1	54	1691
121603	1/ 6/77	5.5		4.0	7.0	8150	304	6064				1	30	2354
121604	4/27/77	5.5	19.0	1.1	7.4	7020	272	5843				1	20	1426
121401	6/25/76	5.5	17.0	1.0	6.9	6900	604	6410				1	20	1525
121402	10/20/76	5.5		0.2	7.6	9040	626	6283				-1	72	1555
121403	1/ 4/77	5.5		1.2	7.7	5060	188	6126				-1	39	1566
121404	4/26/77	5.5	18.0	2.1	7.5	4480	184	3527				-1	31	1454
121301	6/25/76	2.4	17.0	3.4	6.8	6600	320	5587				-1	24	1400
121302	10/20/76	2.4		1.5	7.4	7910	256	5777				-1	60	1555
121303	1/ 4/77	2.4		5.0	7.8	7260	288	5724				1	66	2027
121304	4/26/77	2.4	15.0	3.6	7.0	6720	272	5452				-1	28	1486
121501	6/24/76	2.1	18.0	2.4	6.8	6200	280	5224				-1	68	1349
121502	10/20/76	2.1		2.2	6.8	7480	248	6424				-1	44	1271
121503	1/ 5/77	2.1		2.0	7.1	7820	260	5795				1	37	1920
121504	4/26/77	2.1	14.5	1.1	7.2	4543	272	3904				1	41	971
122201	6/24/76	4.0	18.5	8.0	6.9	6100	304	5941				-1	60	1775
122202	10/22/76	4.0		4.7	7.0	9900	260	6600				-1	64	2106
122204	4/27/77	4.0	18.5	8.5	7.0	6660	276	5517				2	49	1698

TABLE B-1. Continued

SAMPLE NUMBER	COLLECTION DATE	DEPTH M	TEMP DEG C	DISSOLVED OXYGEN MG/L	PH	CONDUC- TIVITY UMHOS/CM	TOTAL ALKALINITY MG/L CACO3	DISSOLVED SOLIDS MG/L	SUSPENDED SOLIDS MG/L	TOTAL SOLIDS MG/L	VOLATILE SUSPENDED SOLIDS MG/L	BOD MG/L	COD MG/L	CL MG/L
122301	6/25/76	7.0	17.0	4.5	6.8	8100	276	6671				-1	101	2090
122302	10/22/76	7.0		3.6	6.9	8814	220	5837				-1	73	1801
122303	1/ 6/77	7.0		3.2	7.0	8100	256	5740				1	42	2183
122304	4/28/77	7.0	16.5	4.5	7.8	7700	220	6200				1	25	2094
120702	10/20/76	33.5		5.1	7.4	7080	148	3976				-1	60	1833
120703	1/ 4/77	33.5		1.3	7.3	6840	176	4394				-1	57	2030
124104	4/26/77	0.6			8.0		132						22	1757
124202	10/20/76	1.2			7.5		404						82	
124204	4/27/77	1.2			7.8		296						26	1909
124302	10/20/76	2.2			7.0		452	6756.0					60	1608
124303	1/ 6/77	2.2			7.7	9600.0	492	7568.0					93	2134
124304	4/28/77	2.2			7.3		380	7068.0					12	1670
124501	9/ 9/76												246	
124502	4/14/77							357.0	595	952			73	

TABLE B-1. Continued

SAMPLE NUMBER	SULFIDE-SULFUR MG/L-S	TOTAL COLIFORM #/100ML	FECAL COLIFORM #/100ML	TOTAL ORGANIC CARBON MG/L-C	DISSOLVED ORGANIC CARBON MG/L-C	TOTAL ORGANIC NITROGEN MG/L-N	SOLUBLE ORGANIC NITROGEN MG/L-N	NH4 MG/L-N	NO3 MG/L-N	TOTAL PHOSPHORUS MG/L-P	SOLUBLE PHOSPHORUS MG/L-P	SOLUBLE ORTHO-PHOSPHATE MG/L-P
116002		0	0				0.4	-0.1	1.6		0.02	-0.01
116003		0	0				0.2	-0.1	-0.1		-0.01	-0.01
116004	-0.1	0	0		-0.5		0.6	0.1	1.5		0.03	0.01
114502							3.9	2.4	0.6			
114601		7167	0				1.6	-0.1	1.9		0.24	0.10
114604	-0.1	1550	6		8.4		0.5	0.1	0.5	0.01	0.01	0.01
114701		99.9	0				1.0	-0.1	2.3		1.90	0.02
110301		99.9	0				1.1	-0.1	2.9		0.04	0.02
110302		0	0				0.2	-0.1	3.0		0.01	-0.01
110303		0	0				0.3	-0.1	-0.1		0.02	0.02
110304	-0.1	0	0		14.6		0.8	0.2	1.4		0.06	0.01
110601		99.9	0				1.4	-0.1	1.1		2.60	0.37
110602		0	0		7.7		-0.1	0.7	1.7		0.04	0.04
110603		35	0				0.6	0.3	-0.1		0.04	0.04
110604	-0.1	99.9	14		14.3		1.4	2.1	-0.1		0.06	0.04
110501		99	0				2.0	-0.1	1.9		1.50	0.32
110502		0	0				0.3	0.2	3.3		0.04	0.04
110503		3	0				0.4	-0.1	-0.1		0.03	0.03
110504	-0.1	0	0		12.8		0.6	-0.1	-0.1		0.07	0.01
124601		100	0	53.3				16.8	3.7	5.20	4.80	3.80
124602		0	0	98.0	57.9	84.0	36.0	23.0	3.7	9.30	7.00	7.80
124603		2	1	32.2	19.3		-0.1	25.2	0.0	9.00	8.00	7.10
124604	0.3	99.9	99.9		28.5	16.9	14.9	25.6	0.1	8.10	7.60	7.20
124605				58.4	17.7	33.9	2.7	23.7	0.4			
124606				60.4	13.9	30.5	1.5	25.5	0.2			

TABLE B-1. Continued

SAMPLE NUMBER	SULFIDE-SULFUR MG/L-S	TOTAL COLIFORM #/100ML	FECAL COLIFORM #/100ML	TOTAL ORGANIC CARBON MG/L-C	DISSOLVED ORGANIC CARBON MG/L-C	TOTAL ORGANIC NITROGEN MG/L-N	SOLUBLE ORGANIC NITROGEN MG/L-N	NH4 MG/L-N	NO3 MG/L-N	TOTAL PHOSPHORUS MG/L-P	SOLUBLE PHOSPHORUS MG/L-P	SOLUBLE ORTHO-PHOSPHATE MG/L-P
122011		1367	0				1.0	0.2	7.0		0.80	0.30
122012		0	0				-0.1	-0.1	12.2		0.04	0.02
122013		1	0				0.2	-0.1	4.7		0.03	0.03
122014	-0.1	14	0		23.7		0.7	0.4	8.9		0.03	0.03
122021		967	0		10.0		1.1	0.1	8.4		3.00	2.40
122022		0	0				0.4	-0.1	14.2		-0.01	-0.01
122023		2	0				0.1	-0.1	6.0		0.04	0.01
122024	-0.1	0	0		8.2		0.2	0.4	11.3		0.03	0.01
122031		3267	0		13.3		1.1	-0.1	8.9		2.80	1.90
122032		0	0				-0.1	-0.1	15.0		0.07	0.07
122033		0	0				4.2	-0.1	8.9		0.03	0.03
122034	-0.1	0	0		9.4		0.1	0.7	11.3		0.02	0.01
120501		900	0		34.0		3.2	-0.1	7.7		2.40	0.54
120502		0	0				0.4	-0.1	5.0		0.04	0.04
120503		352	0		11.3		0.2	0.2	-0.1		0.06	0.06
120504	-0.1	0	0		18.8		0.5	-0.1	3.4		0.01	0.01
120301		1333	33				1.8	-0.1	7.2		0.80	-0.01
120302		0	0				0.4	-0.1	7.5		0.02	0.01
120303		74	68				-0.1	0.4	1.3		0.08	0.06
120304	-0.1	0	0		9.6		-0.1	0.5	5.2		0.02	0.01
120431		133	0		53.0		1.7	-0.1	21.5		0.03	0.02
120432		0	0				0.6	-0.1	6.3		0.04	0.04
120433		0	0				0.4	-0.1	-0.1		0.07	0.06
120434	-0.1	0	0		15.5		1.0	0.3	4.5		0.03	0.01
122101		367	367		10.0		0.9	-0.1	24.4		1.20	0.50

TABLE B-1. Continued

SAMPLE NUMBER	SULFIDE-SULFUR MG/L-S	TOTAL COLIFORM #/100ML	FECAL COLIFORM #/100ML	TOTAL ORGANIC CARBON MG/L-C	DISSOLVED ORGANIC CARBON MG/L-C	TOTAL ORGANIC NITROGEN MG/L-N	SOLUBLE ORGANIC NITROGEN MG/L-N	NH4 MG/L-N	NO3 MG/L-N	TOTAL PHOSPHORUS MG/L-P	SOLUBLE PHOSPHORUS MG/L-P	SOLUBLE ORTHO-PHOSPHATE MG/L-P
122102		167	0		6.4		-0.1	0.2	15.6		0.02	0.02
122103		2	0		4.1		0.2	-0.1	6.6		0.03	0.03
122104	-0.1	6100	0		8.6		1.1	0.6	12.6		0.08	0.03
120901		99.9	800				1.5	-0.1	30.6		0.22	0.02
120902		0	0		3.4		0.1	0.2	19.7		0.05	0.04
120903		0	0				0.6	-0.1	6.4		0.03	0.03
120904	-0.1	3200	10		19.8		2.3	0.8	-0.1		0.04	0.02
121702		0	0				0.2	-0.1	23.8		-0.01	-0.01
121601		99.9	33				2.0	-0.1	4.3		0.05	0.02
121602		0	0				0.3	-0.1	3.1		0.02	0.01
121603		137	0				0.3	0.2	-0.1		0.01	-0.01
121604	-0.1	341	6		14.6		0.5	-0.1	6.5		0.01	0.01
121401		9300	0		9.8		0.9	-0.1	1.9		1.60	-0.01
121402		0	0				0.5	-0.1	1.8		0.19	0.17
121403		42	0				0.4	0.2	-0.1		0.13	0.10
121404	-0.1	0	0		6.1		0.1	0.7	-0.1		0.05	0.03
121301		99.9	0		4.4		1.2	-0.1	18.2		0.20	0.02
121302		0	0				-0.1	-0.1	22.7		0.04	0.04
121303		89	0				0.4	-0.1	18.1		0.04	0.03
121304	-0.1	20	0		16.8		0.4	0.3	5.5		0.03	0.01
121501		4100	133				1.2	-0.1	19.7		4.20	0.15
121502		0	0				-0.1	-0.1	25.8		0.04	0.02
121503		1	0				0.2	-0.1	11.8		0.04	0.04
121504	-0.1	1000	0		9.3		0.7	0.8	15.2		0.04	0.02
122201		100	0		0.0		1.5	-0.1	1.5		0.10	0.06

TABLE B-1. Continued

SAMPLE NUMBER	SULFIDE-SULFUR MG/L-S	TOTAL COLIFORM #/100ML	FECAL COLIFORM #/100ML	TOTAL ORGANIC CARBON MG/L-C	DISSOLVED ORGANIC CARBON MG/L-C	TOTAL ORGANIC NITROGEN MG/L-N	SOLUBLE ORGANIC NITROGEN MG/L-N	NH4 MG/L-N	NO3 MG/L-N	TOTAL PHOSPHORUS MG/L-P	SOLUBLE PHOSPHORUS MG/L-P	SOLUBLE ORTHO-PHOSPHATE MG/L-P
122202		0	0				0.4	0.1	12.6		0.05	0.02
122204	-0.1	0	0				0.5	-0.1	14.0		0.02	0.01
122301		2200	0				1.3	-0.1	9.0		0.04	0.02
122302		0	0				0.1	0.4	9.2		-0.01	-0.01
122303							-0.1	0.6	-0.1		0.02	-0.01
122304	-0.1	0	0		18.4		2.0	-0.1	8.2		0.08	0.01
120702		0	0				0.8	-0.1	2.7		0.02	-0.01
120703		0	0				1.0	-0.1	-0.1		-0.01	-0.01
124104	0.3				13.1		1.5	0.3	44.9			0.25
124202				22.3	22.3		-0.1	-0.1	14.1	0.14		0.09
124204	-0.1						1.8	0.5	26.9			
124302				14.1	14.1		-0.1	-0.1	10.9	0.09		0.09
124303							0.4	0.3	-0.1			0.06
124304	-0.1						1.2	0.4	36.4			0.03
124501						3.6						
124502							4.8	4.3	0.4	5.00		2.70

TABLE B-1. Continued

SAMPLE NUMBER	SO4 MG/L-SO4	AL MG/L-AL	AS UG/L-AS	B UG/L-B	CD UG/L-CD	CA MG/L-CA	CO UG/L-CO	CR UG/L-CR	CU UG/L-CU	FE MG/L-FE	PB UG/L-PB	MG MG/L-MG	MN MG/L-MN
116002	705	-0.3	-20	78	-20	184	-50	-20	-20	0.5	-100	58	-0.05
116003	429	0.5	-20	93	-20	97	-50	-20	-20	-0.5	-100	59	-0.05
116004	454	-0.3	-20	99	-20	178		-20	-20	-0.2		57	0.05
114502	45	78.0			-20	216	-50	51	41	40.0	-200	26	1.05
114601		0.8		195	-10	208	-50	10	90	0.6	30	76	-0.01
114604	713	-0.3	-20	133	-20	349		-20	-20	-0.2		92	-0.05
114701		0.6		208	-10	122	-50	-10	100	0.6	20	53	0.02
110301		7.4		230	-10	249	-50	20	330	7.6	-10	82	0.40
110302	1938	12.1	-20	349	-20	600	-50	55	144	15.4	-100	192	0.46
110303	1556	0.7	-20	227	-20		-50	22	-20	0.8	-100	192	0.24
110304	1621	1.0	-20	263	-20	653		-20	-20	1.6		150	0.26
110601		1.0		240	-10	186	-50	-10	50	0.9	30	65	0.01
110602	1448	0.9	-20	445	-20	405	-50	18	-20	11.7	-100	86	0.34
110603		0.8	-20	204	-20	158	-50	25	-20	-0.5	-100	97	0.22
110604	1608	0.4	-20	209	-20	617		-20	-20	1.2		139	0.48
110501		2.2		220	40	390	-50	10	290	3.1	10	164	0.02
110502	2583	2.6	64	140	-20	605	76	29	24	42.4	-100	229	0.10
110503	2272	0.4	41	226	-20	527	-50	52	-20	-0.5	-100	253	-0.05
110504	1983	-0.3	20	278	-20	605		-20	20	0.3		166	-0.05
124601		1.0		235	-10	124	-50	30	200	0.4	-10	65	0.02
124602	917	-0.3	-20	369	-20	186	-50	-20	37	1.8	-100	59	-0.05
124603	544	0.5	-20	308	-20	262	-50	25	-20	-0.5	-100	86	-0.05
124604	518	-0.3	-20	435	-20	196		23	38	-0.2		59	-0.05
122011		0.9		164	-10	320	-50	10	120	1.0	-10	99	0.06
122012	2111	0.5	22	659	-20	690	-50	-20	37	9.2	-100	177	0.09

TABLE B-1. Continued

SAMPLE NUMBER	SO4 MG/L-SO4	AL MG/L-AL	AS UG/L-AS	B UG/L-B	CD UG/L-CD	CA MG/L-CA	CO UG/L-CO	CR UG/L-CR	CU UG/L-CU	FE MG/L-FE	PB UG/L-PB	MG MG/L-MG	MN MG/L-MN
122013	2234	1.0	-20	250	-20	451	-50	38	-20	-0.5	-100	260	-0.05
122014	1974	-0.3	21	310	-20	828		26	20	-0.2		208	-0.05
122021		0.7		235	-10	278	-50	-10	70	0.4	-10	101	0.02
122022	1846	0.3	-20	651	-20	761	-50	-20	37	10.5	-100	188	0.05
122023	1642	0.8	-20	268	-20	328	-50	32	-20	-0.5	-100	240	-0.05
122024	1983	-0.3	-20	335	-20	778		-20	24	-0.2		199	-0.05
122031		1.6		100	-10	540	-50	20	160	2.0	-10	92	0.18
122032	1726	1.8	20	659	-20	709	-50	-20	22	28.0	-100	193	-0.05
122033	1661	0.5	-20	306	-20	473	-50	32	-20	-0.5	-100	243	-0.03
122034		-0.3	-20	337	-20	821		-20	20	-0.2		195	-0.05
120501		7.5		260	30	429	-50	20	280	4.1	20	60	0.62
120502	2111	1.1	26	633	-20	641	-50	35	26	23	-100	219	0.11
120503	1929	2.2	-20	243	-20	382	-50	38	-20	6.3	-100	295	0.17
120504	3008	-0.3	-20	568	-20	823		26	24	0.5		255	0.23
120301		1.4		248	-10	247	-50	20	330	1.4	-10	[illegible]	0.28
120302	2856	-0.3	-20	556	-20	761	60	-20	22	3.0	-100	233	0.05
120303	2038	1.0	-20	256	-20	336	-50	27	-20	-0.5	-100	230	-0.05
120304	2328	-0.3	-20	359	-20	663		-20	-20	0.5		209	0.13
120431		1.4		270	-10	684	-50	10	270	1.9	-10		0.20
120432	2164	-0.3		924	-20	774	62	23	30	4.0	-100	254	0.08
120433	1862	2.6	-20	153	-20		-50	-20	-20	0.7	-100	132	0.08
120434	2405	-0.3	-20	404	-20	717		-20		0.3		216	0.09
122101		1.7		220	-10	539	-50	10	230	1.1	-10	100	-0.01
122102	1514	0.4	-20	969	-20	544	-50	-20	-20	6.4	-100	144	0.08
122103	1795	6.5	-20	389	-20	498	-50	32	-20	4.0	-100	198	0.14

TABLE B-1. Continued

SAMPLE NUMBER	SO4 MG/L-SO4	AL MG/L-AL	AS UG/L-AS	B UG/L-B	CD UG/L-CD	CA MG/L-CA	CO UG/L-CO	CR UG/L-CR	CU UG/L-CU	FE MG/L-FE	PB UG/L-PB	MG MG/L-MG	MN MG/L-MN
122104	1466	-0.3	-20	413	-20	481		-20	-20	-0.2		120	0.08
120901		1.3		200	-10	235	-50	10	190	0.9	-10	92	0.24
120902	1894	0.9		558	-20	556	-50	-20	-20	10.9	-100	140	0.14
120903	1661	2.7	-20	438	-20	261	-50	-20	-20	0.8	-100	191	0.13
120904	1139	0.8	-20	436	-20	445		-20	-20	0.8		96	0.08
121702	1636	-0.3	-20	695	-20	608	-50	-20	-20	16.8	-100	166	0.17
121601		4.2		195	-10	646	-50	20	360	3.1	30	76	0.24
121602	2118	0.3	20	924	-20	657	52	40	25	7.8	-100	237	0.10
121603	1948	0.7	-20	248	-20	409	-50	38	-20	3.7	-100	274	0.13
121604	2130	-0.3	-20	413	-20	614		-20	-20	0.3		183	0.07
121401		1.9		218	-10	252	-50	20	20	1.9	20	100	0.02
121402	2555	-0.3	-20	154	-20	554	50	-20	-20	10.4	-100	178	0.36
121403	548	0.7	-20	112	-20	261	-50	-20	-20	0.7	-100	114	0.22
121404	569	-0.3	-20	141	-20	391		-20	-20	0.7		103	0.28
121301		1.8		235	-10	664	-50	20	360	1.3	-10	101	0.01
121302	2164	1.7	-20	249	-20	581	-50	31	21	25.0	-100	170	0.06
121303	1766	0.7	-20	298	-20	296	-50		-20	-0.5	-100	202	-0.05
121304	1660	-0.3	-20	353	-20	600		-20	-20	0.2		142	-0.05
121501		1.9		235	-10	245	-50	20 L	70	0.8	10	93	-0.01
121502	1766	-0.3	-20	489	-20	559	-50	23	20	3.6	-100	149	0.06
121503	1905	1.4	-20	281	-20	351	-50	32	-20	1.0	-100	213	-0.05
121504	1260	-0.3	-20	379	-20	542		-20	-20	0.4		111	-0.05
122201		1.2		222	-10	310	-50	20	140	0.8	-10	100	-0.01
122202	1726	-0.3	34	304	-20	721	50	-20	26	5.1	-100	169	-0.05
122204	1535	-0.3	-20	306	20	631		-20	-20	1.0		129	-0.05

TABLE B-1. Continued

SAMPLE NUMBER	SO4 MG/L-SO4	AL MG/L-AL	AS UG/L-AS	B UG/L-B	CD UG/L-CD	CA MG/L-CA	CO UG/L-CO	CR UG/L-CR	CU UG/L-CU	FE MG/L-FE	PB UG/L-PB	MG MG/L-MG	MN MG/L-MN
122301		1.9		198	-10	418	-50	20	190	1.0	-10	98	0.01
122302	1670	-0.3	-20	462	-20	726	54	-20	22	2.6	-100	178	-0.05
122303	1518	5.9	-20	221	-20	690	-50	32	-20	5.0	-100	198	0.16
122304	1639	-0.3	-20	226	-20	852		-20	-20	3.1		153	-0.05
120702	809	-0.3	-20	616	-20	446	-50	-20	102	3.5	-100	129	-0.05
120703	601	4.5	-20	124	-20	475	-50	-20	-20	3.5	-100	145	0.10
124104	1561			383									
124202				640									
124204	2990			828									
124302	3045	-0.3		955	-20	517	-50	-20	33	1.6	-100	195.0	0.05
124303	2827	0.7		474	-20	694	-50	38	36	-0.5	-100	263.0	-0.05
124304	2628			587									
124501		1.9		208	-10	560	-50	20	390	13.0	-10	97.0	1.53
124502	69	141.0			-20	371	-50	165	120	65.0	-200	82.0	2.94

TABLE B-1. Continued

SAMPLE NUMBER	HG UG/L-HG	NI UG/L-NI	K MG/L-K	NA MG/L-NA	ZN UG/L-ZN	SE UG/L-SE	ENDRIN NG/L	LINDANE NG/L	METHOXY-CHLOR NG/L	TOXA-PHENE NG/L	2,4-D NG/L	2,4,5 TP SILVEX NG/L
116002	-2.0	94	3.9	198	106	10	-0.03	40.00	-0.01	-0.1	-1.2	15.0
116003	-0.5	-50	2.1	75	-50	-10	-0.03	8.70	-0.01	-0.1	-2.0	61.8
116004		-50	3.6	186	100	-10	-0.03	1.00	-0.01	-0.1	35.3	16.0
114502		-50	20.0	-5	207		0.00	0.00	0.00	0.0	0.0	0.0
114601	-0.5	-50	6.2	424	-10		-0.03	72.00	-0.01	-0.1	3.8	-0.2
114604		-50	6.0	391	-20	-10	-0.03	1.30	-0.01	-0.1	18.4	5.8
114701	-0.5	-50	2.1	380	70		-0.03	4.10	-0.01	-0.1	0.6	-0.2
110301	-0.5	-50	5.8	346	80		-0.03	-0.10	-0.01	-0.1	0.9	-0.2
110302	-2.0	207	10.0	396	197	12	-0.03	16.20	-0.01	-0.1	-1.2	12.5
110303	0.6	-50	2.4	336	51	-10	-0.03	3.20	-0.01	-0.1	18.2	15.8
110304		-50	5.4	269	51	-10	-0.03	5.30	-0.01	-0.1	15.2	7.7
110601	-0.5	-50	5.3	758	40		-0.03	48.80	-0.01	-0.1	1.8	-0.2
110602	-2.0	94	10.8	865	64	22	-0.03	-5.00	-0.01	-0.1	-1.2	18.0
110603	-0.5	-50	4.9	968	-50	13	-0.03	4.40	-0.01	-0.1	46.4	105.0
110604		-50	13.1	1417	196	58	-0.03	2.00	-0.01	-0.1	17.7	6.9
110501	-0.5	-50	11.0	2128	50		-0.03	5.50	-0.01	-0.1	0.4	-0.2
110502	-2.0	263	17.9	2465	75	76	-0.03	29.00	-0.01	-0.1	-1.2	16.0
110503	-0.5	-50	12.0	2543	59	59	-0.03	5.80	-0.01	-0.1	39.8	70.6
110504		-50	20.0	2083	175	83	-0.03	-0.40	-0.01	-0.1	12.7	6.7
124601	-0.5	-50	14.2	449	100		-0.03	551.00	-0.01	-0.1	0.6	-0.2
124602	-2.0	66	16.8	559	90	15	-0.03	1250.00	-0.01	-0.1	-1.2	20.0
124603	0.6	-50	14.0	506	51	-10	-0.03	380.00	-0.01	-0.1	50.2	70.4
124604		-50	13.7	350	64	-10	-0.03	49.20	-0.01	-0.1	64.0	21.9
122011	-0.5	-50	7.2	1236	70		-0.03	125.00	-0.01	-0.1	0.5	-0.2
122012	-2.0	193	12.0	1227	430	40	-0.03	40.00	-0.01	-0.1	-1.2	21.0

TABLE B-1. Continued

SAMPLE NUMBER	HG UG/L-HG	NI UG/L-NI	K MG/L-K	NA MG/L-NA	ZN UG/L-ZN	SE UG/L-SE	ENDRIN NG/L	LINDANE NG/L	METHOXY-CHLOR NG/L	TOXA-PHENE NG/L	2,4-D NG/L	2,4,5 TP SILVEX NG/L
122013	-0.5	-50	7.7	1419	-50	24	-0.03	3.80	-0.01	-0.1	-2.0	81.8
122014		-50	14.8	1479	20	52	-0.03	2.20	-0.01	-0.1	88.5	10.8
122021	-0.5	-50	5.4	817	50		-0.03	151.00	-0.01	-0.1	0.8	-0.2
122022	-2.0	151	11.4	1111	349	30	-0.03	15.00	-0.01	-0.1	-1.2	39.0
122023	-0.5	-50	6.6	1194	-50	30	-0.03	6.50	-0.01	-0.1	43.8	40.6
122024		-50	13.8	1302	20	38	-0.03	2.40	-0.01	-0.1	-0.4	12.8
122031	-0.5	-50	5.3	118	70		0.03	124.00	-0.01	-0.1	0.6	-0.2
122032	-2.0	179	11.4	995	304	29	-0.03	27.00	-0.01	-0.1	-1.2	15.0
122033	0.6	-50	7.3	757	-50	27	-0.03	9.40	-0.01	-0.1	30.4	53.5
122034		-50	12.9	1292	175	21	-0.03	1.40	-0.01	-0.1	12.6	16.0
120501	-0.5	-50	5.4	1645	660		-0.03	60.50	0.01	-0.1	1.0	-0.2
120502	-2.0	179	12.3	1498	367	38	-0.03	183.00	-0.01	-0.1	-1.2	54.0
120503	0.6	-50	9.8	1590	284	33	-0.03	1.60	-0.01	-0.1	14.4	128.0
120504		-50	16.0	1896	351	52	-0.03	1.80	-0.01	-0.1	52.8	9.1
120301	-0.5	-50	7.3	1333	350		-0.03	252.00	-0.01	-0.1	1.7	-0.2
120302	-2.0	207	13.6	1498	93	38	-0.03	-5.00	-0.01	-0.1	-1.2	19.0
120303	0.6	-50	6.4	1515	-50	29	-0.03	1.80	-0.01	-0.1	53.0	67.7
120304		-50	16.9	1333	87	62	-0.03	1.60	-0.01	-0.1	49.3	16.4
120431	-0.5	-50	6.0	1462	60		-0.03	-0.10	-0.01	-0.1	230.0	-0.2
120432	-2.0	235	14.4	1575	227		-0.03	-5.00	-0.01	-0.1	-1.2	60.0
120433	-0.5	-50	2.7	1399	-50	40	-0.03	4.20	-0.01	-0.1	-2.0	35.2
120434		-50	14.1	1333	51	40	-0.03	0.40	-0.01	-0.1	-0.4	3.7
122101	-0.5	-50	6.8	785	40		-0.03	14.80	-0.01	-0.1	1.5	-0.2
122102	-2.0	122	11.4	856	23	20	-0.03	16.00	-0.01	-0.1	-1.2	31.5
122103	0.6	-50	8.6	1118	-50	21	-0.03	3.60	-0.01	-0.1		

TABLE B-1. Continued

SAMPLE NUMBER	HG UG/L-HG	NI UG/L-NI	K MG/L-K	NA MG/L-NA	ZN UG/L-ZN	SE UG/L-SE	ENDRIN NG/L	LINDANE NG/L	METHOXY-CHLOR NG/L	TOXA-PHENE NG/L	2,4-D NG/L	2,4,5 TP SILVEX NG/L
122104		-50	8.9	776	113	15	-0.03	0.80	-0.01	-0.1	-0.4	10.1
120901	-0.5	-50	7.0	559	30		-0.03	5.00	-0.01	-0.1	-0.4	-0.2
120902	-2.0	151	13.0	685	83		-0.03	-5.00	-0.01	-0.1	-1.2	17.0
120903	-0.5	-50	5.9	1058	107	25	-0.03	4.70	-0.01	-0.1	-2.0	42.4
120904		-50	8.0	531	82	-10	-0.03	-0.40	-0.01	-0.1	18.0	11.1
121702	-2.0	151	10.6	920	146	28	-0.03	850.00	-0.01	-0.1	-1.2	12.7
121601	-0.5	-50	8.0	946	100		-0.03	6.40	-0.01	-0.1	1.6	-0.2
121602	-2.0	200	10.4	1014	78	29	-0.03	82.20	-0.01	-0.1	-1.2	46.5
121603	0.7	-50	5.6	1169	212	22	-0.03	8.90	-0.01	-0.1	-2.0	90.6
121604		-50	9.2	1000	144	22	-0.03	4.50	-0.01	-0.1	52.7	11.6
121401	-0.5	-50	8.1	1010	170		-0.03	200.00	-0.01	0.1	4.2	-0.2
121402	-2.0	221	15.3	1459	62	32	-0.03	810.00	-0.01	-0.1	-1.2	19.0
121403	-0.5	-50	4.8	637	-50	10	-0.03	13.30	-0.01	-0.1	-2.0	74.7
121404		-50	7.7	653	92	14	-0.03	3.50	-0.01	-0.1	6.6	0.0
121301	-0.5	-50	4.5	903	90		-0.03	12.20	-0.01	-0.1	1.6	-0.2
121302	-2.0	172	13.1	1052	91	28	-0.03	68.00	-0.01	-0.1	-1.2	25.0
121303	-0.5	-50	7.3	1219	103	22	-0.03	6.40	-0.01	-0.1	-2.0	59.2
121304		-50	10.2	970	56	22	-0.03	-0.40	-0.01	-0.1	-0.4	19.5
121501	-0.5	-50	9.4	795	-10		-0.03	53.70	-0.01	-0.1	1.0	-0.2
121502	-2.0	136	17.6	847	50	32	-0.03	23.00	-0.01	-0.1	-1.2	-12.5
121503	-0.5	-50	12.0	1118	-50	47	-0.03	2.40	-0.01	-0.1		
121504		-50	10.0	653	144	26	-0.03	5.70	-0.01	-0.1		7.3
122201	-0.5	-50	7.0	1118	60		-0.03	-0.10	-0.01	-0.1	0.7	-0.2
122202	-2.0	179	10.6	1265	80	52	-0.03	26.00	-0.01	-0.1	-1.2	-12.5
122204		-50	9.5	980	165	23	-0.03	1.10	-0.01	-0.1	-0.4	18.4

TABLE B-1. Continued

SAMPLE NUMBER	HG UG/L-HG	NI UG/L-NI	K MG/L-K	NA MG/L-NA	ZN UG/L-ZN	SE UG/L-SE	ENDRIN NG/L	LINDANE NG/L	METHOXY-CHLOR NG/L	TOXA-PHENE NG/L	2,4-D NG/L	2,4,5 TP SILVEX NG/L
122301	-0.5	-50	5.9	1053	310		-0.03	4.10	-0.01	-0.1	0.9	-0.2
122302	-2.0	193	9.3	956	160	38	-0.03	19.00	-0.01	-0.1	-1.2	15.0
122303	0.7	-50	6.5	1149	-50	23	-0.03	27.40	-0.01	-0.1	44.0	210.0
122304		-50	9.8	933	82	37	-0.03	1.50	-0.01	-0.1	54.0	6.2
120702	-2.0	122	10.3	847	67	39	-0.03	68.00	-0.01	-0.1	-1.2	19.0
120703	-0.5	-50	6.9	978	220	23	-0.03	11.80	-0.01	-0.1	9.6	41.0
124104												
124202												
124204												
124302	35.0	207	13.7	1769	179							
124303		-50	9.0	416	300		-0.03		-0.01	-0.1		
124304												
124501	-0.5	230	10.2	1526	50							
124502		-50	41.0	71	601							

TABLE B-2. SOIL DATA

SAMPLE NUMBER	COLLECTION DATE	DEPTH M	PH	INORGANIC NITROGEN UG/GM-N	TOTAL ORGANIC NITROGEN UG/GM-N	TOTAL PHOSPHORUS UG/GM-P	AVAILABLE PHOSPHORUS UG/GM-P	TOTAL SULFUR UG/GM-S
11111	7/ 2/76	0.01	8.0		1094	1524	10	
11131	1/ 6/77	0.01	8.6	14.4	1992	1215	41	649
11112	7/ 2/76	0.03	7.7		935	1093	6	
11132	1/ 6/77	0.03	8.6	11.4	1395	1106	30	1066
11113	7/ 2/76	0.10	7.8	45.7	763	1114	5	2905
11133	1/ 6/77	0.10	8.5	19.3	1096	955	28	979
11114	7/ 2/76	0.30	7.6	68.4	842	856	3	10260
11134	1/ 6/77	0.30	8.4	10.3	697	916	23	1775
11115	7/ 2/76	1.00	7.7	63.6	550	737	20	16940
11135	1/ 6/77	1.00	7.8	17.7	290	779	8	
11116	7/ 2/76	3.00	7.8	49.2	299	791	2	23680
11136	1/ 6/77	3.00	7.9	7.0	297	382	-1	14080
11211	7/ 2/76	0.01	7.7	90.0	882	1007	18	
11231	1/ 6/77	0.01	8.0	20.4	2497	1145	27	8508
11212	7/ 2/76	0.03	7.8	39.5	1376	985	13	5813
11232	1/ 6/77	0.03	8.1	20.8	1296	1141	29	9848
11213	7/ 2/76	0.10	7.7	72.5	1147	1201	17	6297
11233	1/ 6/77	0.10	8.0	16.6	576	928	18	8814
11214	7/ 2/76	0.30	7.6		900	813	10	14010
11234	1/ 6/77	0.30	8.0	14.0	397	894	3	9643
11215	7/ 2/76	1.00	7.6	21.4	288	877	10	
11235	1/ 6/77	1.00	7.9	12.3	394	726	10	5029
11216	7/ 2/76	3.00	7.9	43.7	165	823	2	4100
11236	1/ 6/77	3.00	8.1	14.7	296	866	-1	4464
11311	7/ 2/76	0.01	7.8	24.1	991	1039	3	1060

TABLE B-2. Continued

SAMPLE NUMBER	COLLECTION DATE	DEPTH M	PH	INORGANIC NITROGEN UG/GM-N	TOTAL ORGANIC NITROGEN UG/GM-N	TOTAL PHOSPHORUS UG/GM-P	AVAILABLE PHOSPHORUS UG/GM-P	TOTAL SULFUR UG/GM-S
11331	1/ 6/77	0.01	8.1	13.0	1396	1284	19	2176
11312	7/ 2/76	0.03	7.6	42.9	1569	953	5	4020
11332	1/ 6/77	0.03	8.2	13.2	1196	1084	22	2175
11313	7/ 2/76	0.10	8.1	61.4	1043	1093	14	1670
11333	1/ 6/77	0.10	8.1	15.5	696	981	23	2167
11314	7/ 2/76	0.30	7.5	57.5	950	899	8	10827
11334	1/ 6/77	0.30	8.2	14.3	795	752	7	3389
11315	7/ 2/76	1.00	7.8	11.1	999	1028	1	23960
11335	1/ 6/77	1.00	7.8	15.8	493	620	5	38310
11316	7/ 2/76	3.00	8.0	40.4	470	597	2	2561
11336	1/ 6/77	3.00	7.9	21.3	197	528	-1	41420
12111	7/ 2/76	0.01	8.0		1301	1115	17	2326
12131	1/ 5/77	0.01	8.4	28.1	2895	2051	45	1032
12112	7/ 2/76	0.03	7.9		1296	1266	39	7110
12132	1/ 5/77	0.03	8.2	60.7	1396	1976	53	1644
12113	7/ 2/76	0.10	7.9	43.9	1668	1546	58	767
12133	1/ 5/77	0.10	8.1	62.7	996	1817	33	2162
12114	7/ 2/76	0.30	7.8	86.5	720	1115	2	7612
12134	1/ 5/77	0.30	7.9	23.8	592	1410	7	8579
12115	7/ 2/76	1.00	7.7	18.5	392	446	1	17940
12135	1/ 5/77	1.00	7.8	14.0	494	869	2	13595
12116	7/ 2/76	3.00	7.7	34.0	168	769	2	4330
12136	1/ 5/77	3.00	8.1	11.2	196	733	-1	1611
12211	7/ 2/76	0.01	7.8		2959	1632	73	
12231	1/ 5/77	0.01	8.5	47.1	2394	1514	18	989

TABLE B-2. Continued

SAMPLE NUMBER	COLLECTION DATE	DEPTH M	PH	INORGANIC NITROGEN UG/GM-N	TOTAL ORGANIC NITROGEN UG/GM-N	TOTAL PHOSPHORUS UG/GM-P	AVAILABLE PHOSPHORUS UG/GM-P	TOTAL SULFUR UG/GM-S
12212	7/ 2/76	0.03	8.0		2195	1708	38	2209
12232	1/ 5/77	0.03	8.4	61.9	1996	1492	21	1167
12213	7/ 2/76	0.10	7.9	95.5	1417	1438	41	
12233	1/ 5/77	0.10	8.4	58.8	1296	1580	68	1077
12214	7/ 2/76	0.30	7.8	61.2	78	1028	4	3977
12234	1/ 5/77	0.30	8.2	27.6	989	1508	44	1401
12215	7/ 2/76	1.00	7.7	45.9	160	759	2	13940
12235	1/ 5/77	1.00	8.1	16.2	294	671	4	5940
12216	7/ 2/76	3.00	8.4	46.1	158	705	4	1661
12236	1/ 5/77	3.00	8.4	22.7	184	566	4	2594
12311	7/ 2/76	0.01			1749	1632	67	
12331	1/ 5/77	0.01	8.4	34.6	1991	1828	126	630
12312	7/ 2/76	0.03	8.2		1895	1481	67	
12332	1/ 5/77	0.03	8.5	56.4	1686	1962	90	688
12313	7/ 2/76	0.10	8.0	80.6	1760	1675	62	5204
12333	1/ 5/77	0.10	8.5	47.2	1095	1723	94	713
12314	7/ 2/76	0.30	8.2	114.2	901	1007	3	2192
12334	1/ 5/77	0.30	8.7	22.6	1092	978	10	839
12315	7/ 2/76	1.00	7.5	48.1	264	662	9	16070
12335	1/ 5/77	1.00	7.7	20.7	493	523	14	20159
12316	7/ 2/76	3.00	7.9	45.6	363	974	18	2401
12336	1/ 5/77	3.00	8.1	23.1	490	741	5	6912

TABLE B-2. Continued

SAMPLE NUMBER	CATION EX-CAP MEQ/1000	EXTR. AL UG/GM	EXTR. B UG/GM	EXTR. CD UG/GM	EXTR. CO UG/GM	EXTR. CR UG/GM	EXTR. CU UG/GM	EXTR. FE UG/GM	EXTR. PB UG/GM	EXCH. MG MG/GM	EXTR. MN UG/GM
11111	31			0.07	-0.12	-1.20	1.6	11	1.7		25
11131	24	-3.0	0.62	-0.05	-0.12	-0.10	0.6	8		0.70	16
11112	29			0.09	-0.12	-1.20	1.7	13	2.2	1.10	30
11132	25	-3.0	0.72	-0.05	-0.12	-0.10	0.5	7		0.80	13
11113	26			0.08	0.12	-1.20	1.7	17	2.2	1.10	34
11133	24	-3.0	0.29	-0.05	-0.12	-0.10	0.5	6		0.80	13
11114	27		0.85	0.03	-0.12	-1.20	1.3	12	1.6	1.20	28
11134	22	-3.0	0.29	-0.05	-0.12	-0.10	0.5	5		0.70	12
11115	22	2.0	0.81	0.03	-0.12	-1.20	1.3	10	1.4	1.80	19
11135	24	-3.0	0.15	-0.05	-0.12	-0.10	4.1	5		0.70	9
11116	32	6.0	1.02	0.02	-0.12	-1.20	1.3	14	2.0	1.70	14
11136	24	-3.0	0.10	-0.05	-0.12	-0.10	0.9	7		0.80	8
11211	27			0.07	-0.12	-1.20	1.2	9	1.7	1.00	23
11231	27	-3.0	1.23	-0.05	-0.12	-0.10	0.6	8		0.70	13
11212	30			0.05	-0.12	-1.20	1.1	9	1.5	1.00	27
11232	26	-3.0	0.57	-0.05	-0.12	-0.10	0.7	8		0.70	13
11213	27			0.04	-0.12	-1.20	0.9	7	1.4	0.90	25
11233	28	-3.0	0.78	-0.05	-0.12	-0.10	0.6	7		0.80	19
11214	31		1.63	0.03	-0.12	-1.20	1.0	7		1.00	20
11234	26	-3.0	0.54	-0.05	-0.12	-0.10	0.6	3		0.70	8
11215	25	13.0	0.72	-0.02	-0.12	-1.20	1.1	6	0.8	1.20	16
11235	32	-3.0	0.48	-0.05	-0.12	-0.10	2.7	10		1.30	14
11216	29	3.0	1.28	0.05	-0.12	-1.20	1.6	21	1.3	1.60	
11236	26	-3.0	0.32	-0.05	-0.12	-0.10	3.8	13		1.20	15
11311	19			0.06	-0.12	-1.20	1.1	8	1.4	1.00	24

TABLE B-2. Continued

SAMPLE NUMBER	CATION EX-CAP MEQ/100G	EXTR. AL UG/GM	EXTR. B UG/GM	EXTR. CD UG/GM	EXTR CO UG/GM	EXTR CR UG/GM	EXTR. CU UG/GM	EXTR. FE UG/GM	EXTR. PB UG/GM	EXCH. MG MG/GM	EXTR MN UG/GM
11331	29	-3.0	0.34	-0.05	-0.12	-0.10	0.8	8		0.80	14
11312	20			0.08	-0.12	-1.20	1.3	10	1.8	1.00	31
11332	28	-3.0	0.54	-0.05	-0.12	-0.10	1.0	9		1.00	20
11313	26		1.12	0.05	0.15	-1.20	0.9	7	1.5	0.90	29
11333	28	-3.0	0.26	-0.05	-0.12	-0.10	0.8	10		1.00	13
11314	22	2.0	0.85	0.05	-0.12	-1.20	1.0	7	1.3	0.80	21
11334	26	-3.0	0.36	-0.05	-0.12	-0.10	1.5	5		0.90	12
11315	20		1.06	-0.02	-0.12	-1.20	1.2	7	0.9	1.20	18
11335	31	-3.0	0.84	-0.05	-0.12	-0.10	1.1	8		1.20	12
11316	18		0.54	-0.02	-0.12	-1.20	1.7	21	1.1	1.60	
11336	33	-3.0	0.85	-0.05	-0.12	-0.10	2.1	8		1.20	7
12111	22			0.38	-0.12	-1.20	1.6	13	2.3	1.10	23
12131	18	-3.0	1.50	0.07	-0.12	-0.10	1.6	17		0.80	25
12112	19			0.10	0.25	-1.20	1.7	16	2.5	1.00	38
12132	34	-3.0	0.95	0.06	-0.12	-0.10	1.3	10		0.90	14
12113	31			0.09	0.30	-1.20	1.8	20	2.8	1.10	52
12133	34	-3.0	0.70	0.05	-0.12	-0.10	1.6	9		0.90	16
12114	19		0.69	0.05	-0.12	-1.20	1.4	9	1.4	1.00	25
12134	30	-3.0	1.52	-0.05	-0.12	-0.10	3.1	9		0.70	17
12115	32	2.0	0.71	-0.02	0.12	-1.20	1.4	15	1.0	1.10	300
12135	31	-3.0	1.27	-0.05	-0.12	-0.10	3.9	20		0.90	13
12116	24	2.0	0.97	0.15	-0.12	-1.20	2.9	31	4.8	1.70	70
12136	25	-3.0	0.95	-0.05	-0.12	-0.10	1.4	13		1.00	11
12211	26			0.10	0.15	-1.20	2.1	15	2.7	1.10	24
12231	30	-3.0	1.20	-0.05	-0.12	-0.10	1.4	13		0.90	12

TABLE B-2. Continued

SAMPLE NUMBER	CATION EX-CAP MEQ/1000	EXTR. AL UG/GM	EXTR. B UG/GM	EXTR. CD UG/GM	EXTR. CO UG/GM	EXTR. CR UG/GM	EXTR. CU UG/GM	EXTR. FE UG/GM	EXTR. PB UG/GM	EXCH. MG MG/GM	EXTR. MN UG/GM
12212	34			0.11	0.32	-1.20	2.2	18	3.1	1.10	560
12232	30	-3.0	1.12	-0.05	-0.12	-0.10	1.3	12		1.00	13
12213	39			0.10	0.25	-1.20	1.7	13	2.6	1.00	78
12233	32	-3.0	0.93	-0.05	-0.12	-0.10	1.5	14	0.0	0.90	18
12214	34	2.0	0.66	0.06	-0.12	-1.20	1.5	12	1.7	1.30	140
12234	36	-3.0	0.87	0.05	-0.12	-0.10	4.0	11		0.90	14
12215	30	2.0	0.62	-0.02	0.15	-1.20	1.9	18	2.5	1.50	8
12235	40	-3.0	0.51	-0.05	-0.12	-0.10	4.0	20		1.20	7
12216	26	2.0	0.54	-0.02	0.25	-1.20	2.5	21		0.90	13
12236	34	-3.0	0.79	-0.05	-0.12	-0.10	3.3	18		1.00	6
12311	28			0.09	0.17	-1.20	1.8	12	2.4	2.00	24
12331	29	-3.0	1.40	-0.05	-0.12	-0.10	1.4	17		1.00	13
12312	27			0.12	-0.12	-1.20	1.6	13	2.3	1.20	22
12332	33	-3.0	1.40	-0.05	-0.12	-0.10	1.2	14		1.00	10
12313	51			0.10	-0.12	-1.20	1.7	14	2.4	1.30	28
12333	32	-3.0	1.11	-0.05	-0.12	-0.10	1.3	15		0.90	13
12314	33	2.0	1.77	0.04	0.43	-1.20	1.8	16		1.60	26
12334	30	-3.0	1.32	-0.05	-0.12	-0.10	2.2	8		1.10	8
12315	26	3.0	1.30	-0.02	0.14	-1.20	1.5	17	4.2	1.60	8
12335	32	-3.0	1.10	-0.05	-0.12	-0.10	3.4	30	0.0	1.00	8
12316	21	1.0	1.60	-0.02	-0.12	-1.20	1.2	11	1.7	1.10	6
12336	27	-3.0	0.50	-0.05	-0.12	-0.10	1.9	27		0.70	7

TABLE B-2. Continued

SAMPLE NUMBER	EXTR NI UG/GM	EXCH K MG/GM	EXCH NA MG/GM	EXTR ZN UG/GM	ENDRIN NG/GM	LINDANE NG/GM	METHOXYCHLOR NG/GM	TOXAPHENE NG/GM	2,4-D NG/GM	SILVEX NG/GM	TOTAL AL MG/GM	TOTAL CD UG/GM	TOTAL CA MG/GM
11111	0.4			1.29	4.6	16.00	-0.01	-0.6	0.20	-0.03	16	-5	25
11131	-0.1	0.3	0.2	1.00	-15.2	9.84	-0.01	-7.6	2.81	13.55	16	1	21
11112	0.4	1.0	1.7	1.65	4.3	0.30	-0.01	-0.6	0.10	-0.03	23	-5	29
11132	0.1	0.3	0.5	0.80	-15.2	3.58	-0.01	-7.6	5.43	28.61	35	1	26
11113	0.5	1.1	1.5	0.96	8.7	3.40	-0.01	-0.6	0.10	-0.03	19	-5	25
11133	-0.1	0.3		0.80	-15.2	47.38	-0.01	-7.6	2.53	13.25	32	2	30
11114	0.3	1.2	2.0	0.98							31	-5	50
11134	-0.1	0.2	1.0	1.00							26	1	28
11115	0.2	0.8	3.5	0.42							14	-5	35
11135	-0.1	0.2	0.7	3.30							17	1	61
11116	0.2	0.9	3.5	0.34							13	-5	53
11136	-0.1	0.2	0.6	0.60							17	-1	56
11211	0.3	0.8	2.5	0.69	5.7	16.30	-0.01	-0.6	0.40	-0.03	20	-5	34
11231	-0.1	0.3	0.5	0.60	-15.2	19.27	-0.01	-7.6	1.85	12.38	19	2	38
11212	0.2	1.0	1.6	1.03	8.4	3.90	-0.01	-0.6	0.20	-0.03	16	-5	34
11232	-0.1	0.3	0.6	1.00	-15.2	2.58	-0.01	-7.6	1.72	33.00	14	-1	28
11213	0.3	1.0	1.6	0.81	16.0	0.90	-0.01	-0.6	0.10	0.03	25	-5	68
11233	-0.1	0.3	0.6	0.80	-15.2	2.66	-0.01	-7.6	1.77	13.31	21	1	33
11214	0.3	1.0	1.5								17	-5	44
11234	-0.1	0.3	0.6	0.40							19	-1	30
11215	0.1	0.6	2.0	0.45							12	-5	40
11235	-0.1	0.3	1.1	1.20							19	1	50
11216	0.4	1.2	3.4	0.76							28	-5	51
11236	0.1	0.3	2.1	1.30							20	1	47
11311	0.2	0.8	1.9	0.99	14.6	1.20	-0.01	-0.6	0.10	-0.03	16	-5	24

TABLE B-2. Continued

SAMPLE NUMBER	EXTR NI UG/GM	EXCH K MG/GM	EXCH NA MG/GM	EXTR ZN UG/GM	ENDRIN NG/GM	LINDANE NG/GM	METHOXYCHLOR NG/GM	TOXAPHENE NG/GM	2,4-D NG/GM	SILVEX NG/GM	TOTAL AL MG/GM	TOTAL CD UG/GM	TOTAL CA MG/GM
11331	0.2	0.4	0.9	0.80	-15.2	9.75	-0.01	-7.6	0.98	15.67	30	1	32
11312	0.6	0.8	1.4	1.21	15.2	2.50	-0.01	-0.6	0.02	-0.03	18	-5	21
11332	0.3	0.6	1.2	0.70	-15.2	7.87	-0.01	-7.6	2.34	7.07	26	2	34
11313	0.3	0.9	1.4	0.90	15.2	1.00	-0.01	-0.6	0.05	-0.03	18	-5	24
11333	0.2	0.4		0.80	-15.2	18.30	-0.01	-7.6	2.03	3.28	15	-1	23
11314	0.4	0.9	1.5	0.90							12	-5	40
11334	0.2	0.3	0.6	1.60							29	1	36
11315	0.4	0.8	1.9	0.70							10	-5	38
11335	-0.1	0.3	1.2	0.40							16	-1	40
11316	0.3	1.2	3.8	0.87							7	-5	47
11336	-0.1	0.2	1.6	0.50							16	-1	50
12111	0.7	1.5	1.9	2.01	16.0	0.40	-0.01	-0.6	0.10	-0.03	14	-5	26
12131	0.4	0.5		2.10	-15.2	-0.38	-0.01	-7.6	3.91	11.58	34	2	39
12112	0.6	1.2	1.8	2.13	7.0	0.50	-0.01	-0.6	0.02	-0.03	15	-5	28
12132	0.3	0.5	0.7	0.70	-15.2	-0.38	-0.01	-7.6	5.36	8.97	30	2	27
12113	0.7	1.6	1.6	2.75	11.8	0.50	-0.01	-0.6	0.10	-0.03	10	-5	26
12133	0.3	0.5	0.7	2.00	-15.2	-0.38	-0.01	-7.6	3.38	15.04	25	1	33
12114	0.4	1.6	1.6	1.32							17	-5	37
12134	0.3	0.4	0.6	2.00							19	1	34
12115	0.2	0.9	2.0	0.30							16	-5	72
12135	0.3	0.5		0.80							16	1	40
12116	1.0	1.5	3.3	2.18							30	-5	9
12136	-0.1	0.3	0.6	0.90							21	1	57
12211	0.7	1.6	3.1	2.88	13.2	0.30	-0.01	-0.6	-0.02	-0.03	16	-5	35
12231	0.4	0.6	0.6	1.60	-15.2	-0.38	-0.01	-7.6	-0.34	0.40	26	1	41

TABLE B-2. Continued

SAMPLE NUMBER	EXTR NI UG/GM	EXCH K MG/GM	EXCH NA MG/GM	EXTR ZN UG/GM	ENDRIN NG/GM	LINDANE NG/GM	METHOXYCHLOR NG/GM	TOXAPHENE NG/GM	2,4-D NG/GM	SILVEX NG/GM	TOTAL AL MG/GM	TOTAL CD UG/GM	TOTAL CA MG/GM
12212	0.7	1.8	1.8	2.88	11.1	0.50	-0.01	-0.6	-0.02	-0.03	18	-5	26
12232	0.4	0.6	1.0	2.40	-15.2	-0.38	-0.01	-7.6	4.86	6.32	27	2	40
12213	0.6	1.7	2.1	1.93	11.8	0.30	-0.01	-0.6	0.10	-0.03	16	-5	26
12233	0.3	0.6	1.4	2.90	-15.2	-0.38	-0.01	-7.6	1.28	4.21	22	2	35
12214	0.5	1.8	2.0	0.69							20	-5	26
12234	0.3	0.5	0.9	3.20							30	2	37
12215	0.5	1.4	3.0	0.31							17	-5	37
12235	0.3	0.4	1.6	1.20							23	1	27
12216	0.7	0.8	3.8	0.55							31	-5	39
12236	-0.1	0.3	1.3	1.00							24	1	26
12311	0.5	1.7	2.1	2.46	12.5	0.50	-0.01	-0.6	0.02	-0.03	17	-5	20
12331	0.3	0.5	0.4	1.60	-15.2	-0.38	-0.01	-7.6	1.25	6.03	29	5	29
12312	0.8	1.7	1.9	2.17	12.5	0.50	-0.01	-0.6	0.04	-0.03	21	-5	22
12332	0.3	0.5	1.3	1.70	-15.2	-0.38	-0.01	-7.6	4.44	12.00	31	2	31
12313	0.6	1.7	1.9	3.12	12.8	0.80	-0.01	-0.6	-0.02	-0.03	27	-5	21
12333	0.3	0.5	0.8	2.20	-15.2	-0.38	-0.01	-7.6	3.24	6.77	21	-1	13
12314	0.6	1.6	2.2	1.06							19	-5	21
12334	0.3	0.5	1.0	1.40							37	-1	38
12315	0.6	1.0	2.5	0.67							17	-5	18
12335	0.3	0.4	1.0	2.00							28	8	26
12316	0.7	0.9	2.4	0.46							17	-5	16
12336	0.2	0.1		1.50							24	-1	13

TABLE B-2. Continued

SAMPLE NUMBER	TOTAL CO UG/GM	TOTAL CR UG/GM	TOTAL CU UG/GM	TOTAL FE MG/GM	TOTAL PB UG/GM	TOTAL MG MG/GM	TOTAL MN UG/GM	TOTAL HG UG/GM	TOTAL NI UG/GM	TOTAL K MG/GM	TOTAL NA MG/GM	TOTAL ZN UG/GM	TOTAL AS UG/GM	TOTAL SE UG/GM
11111	10	32	22	33	-5	6.6	405		16.0	15.0	7.2	61		
11131	14	29	19	18	-10	3.7	397	-0.5	18.0	14.0	6.1	54	20	-1
11112	-10	31	19	38	-5	7.4	334		17.0	13.0	6.2	60		
11132	9	22	20	21	-10	7.3	531	-0.5	3.3	6.0	8.0	64	19	-1
11113	10	32	19	33	-5	6.2	411		19.0	15.0	6.9	62	3	-1
11133	9	29	20	23	-10	9.2	560	-0.5	8.9	7.0	8.4	63	19	-1
11114	-10	36	20	46	-5	11.0	465		19.0	14.0	7.5	75	5	2
11134	10	26	20	20	-10	7.4	502	-0.5	6.0	6.9	7.3	61	21	-1
11115	10	28	19	32	-5	4.2	452	-1.0	18.0	17.0	5.8	64	4	-1
11135	9	20	33	17	-10	12.0	292	-0.5	33.0	14.0	7.5	64	14	-1
11116	-10	20	14	33	-5	5.0	271		9.7	9.3	6.1	50	5	-1
11136	14	24	18	24	-10	4.2	0	-0.5	7.0	5.2	5.6	56	24	-1
11211	-10	32	19	31	-5	8.5	378		16.0	15.0	7.4	59		
11231	9	31	18	19	-10	7.8	520	-0.5	7.0	17.0	7.5	66	27	1
11212	10	32	20	30	-5	4.7	338		17.0	15.0	6.4	52	2	-1
11232	9	24	14	13	-10	4.5	388	-0.5	9.0	18.0	6.5	57	21	-1
11213	-10	24	15	20	-5	14.0	370		12.0	13.0	7.5	78	4	-1
11233	12	18	14	20	-10	4.6	488	-0.5	-0.1	7.0	6.9	61	19	-1
11214	-10	30	19	33	-5	8.7	411	-1.0	16.0	12.0	6.5	70	19	-1
11234	7	24	14	15	-10	4.8	407	-0.5	14.0	19.0	6.5	55	21	-1
11215	-10	24	17	22	-5	5.2	545	-1.0	12.0	14.0	6.9	53	8	-1
11235	14	33	20	19	-10	7.3	621	-0.5	13.0	6.8	5.3	70	19	-1
11216	10	34	22	40	-5	12.0	636	-1.0	18.0	14.0	7.2	6	26	1
11236	9	22	21	30	-10	3.7	814	-0.5	20.0	6.1	6.0	55	42	-1
11311	12	36	18	27	-5	3.6	386		17.0	15.0	6.8	74	19	-1

TABLE B-2. Continued

SAMPLE NUMBER	TOTAL CD UG/GM	TOTAL CR UG/GM	TOTAL CU UG/GM	TOTAL FE MG/GM	TOTAL PB UG/GM	TOTAL MG MG/GM	TOTAL MN UG/GM	TOTAL HG UG/GM	TOTAL NI UG/GM	TOTAL K MG/GM	TOTAL NA MG/GM	TOTAL ZN UG/GM	TOTAL AS UG/GM	TOTAL SE UG/GM
11331	9	24	17	23	-10	5.6	493	-0.5	11.0	9.6	5.9	61	25	-1
11312	-10	32	19	24	-5	6.0	348		17.0	12.0	6.5	53		
11332	9	22	16	22	-10	1.4	339	-0.5	-0.1	5.1	3.6	54	19	-1
11313	10	32	18	29	-5	5.9	360		14.0	15.0	6.5	53	19	-1
11333	9	27	16	15	-10	3.3	335	-0.5	8.9	20.0	4.8	54	20	-1
11314	-10	26	19	26	-5	5.9	364	-1.0	15.0	11.0	6.2	56	18	2
11334	9	26	19	22	-10	4.6	416	-0.5	7.0	5.5	6.8	56	23	-1
11315	-10	27	16	20	-5	4.7	360	-1.0	12.0	15.0	7.1	51	14	-1
11335	-5	24	15	19	-10	4.2	376	-0.5	11.0	6.5	3.1	62	9	-1
11316	15	28	21	37	-5	5.0			23.0	12.0	5.2	58	32	1
11336	8	18	14	17	-10	3.5	348	-0.5	3.2	10.0	4.2	48	20	1
12111	10	32	20	25	-5	6.0	380		16.0	14.0	6.0	66		
12131	12	33	19	26	-10	5.5	455	-0.5	8.9	6.3	6.5	74	24	3
12112	10	34	21	27	-5	5.3	418		16.0	16.0	6.0	72		
12132	9	31	18	24	-10	6.2	447	-0.5	-0.1	7.0	6.0	73	17	1
12113	10	36	22	33	-5	5.0	357		18.0	8.0	5.5	64		
12133	12	29	19	23	-10	4.2	473	-0.5	3.3	7.1	5.6	78	21	2
12114	12	32	27	28	-5	1.1	551	-1.0	19.0	17.0	6.1	80	26	1
12134	7	18	15	20	-10	3.5	378	-0.5	-0.1	6.2	5.5	59	19	2
12115	12	29	20	53	-5	7.8		-1.0	16.0	11.0	5.3	54	26	1
12135	9	28	17	18	-10	4.1	430	-0.5	1.4	13.0	4.2	63	9	1
12116	10	40	45	60	-5	5.5	157	-1.0	16.0	8.0	4.4	92	27	2
12136	14	29	15	27	-10	1.4	733	-0.5	15.0	6.2	4.4	61	27	2
12211	10	34	21	32	-5	8.3	370		14.0	16.0	7.5	75		
12231	9	25	16	22	-10	4.6	359	-0.5	3.3	6.3	5.3	74	20	1

TABLE B-2. Continued

SAMPLE NUMBER	TOTAL CD UG/GM	TOTAL CR UG/GM	TOTAL CU UG/GM	TOTAL FE MG/GM	TOTAL PB UG/GM	TOTAL MG MG/GM	TOTAL MN UG/GM	TOTAL HG UG/GM	TOTAL NI UG/GM	TOTAL K MG/GM	TOTAL NA MG/GM	TOTAL ZN UG/GM	TOTAL AS UG/GM	TOTAL SE UG/GM
12212	10	36	23	34	-5	5.5	357		15.0	17.0	4.5	74		
12232	14	28	16	24	-10	3.7	342	-0.5	7.0	5.5	5.9	73	21	1
12213	-10	34	21	34	-5	6.2	351		15.0	12.0	5.1	72		
12233	7	26	15	21	-10	2.8	304	-0.5	3.2	5.9	4.3	67	25	2
12214	-10	35	22	24	-5	8.4	318	-1.0	15.0	14.0	5.3	69	27	-1
12234	12	29	19	25	-10	4.2	320	-0.5	7.0	7.1	4.3	76	18	3
12215	-10	32	22	32	-5	8.4	217	-1.0	17.0	17.0	4.5	74	30	-1
12235	9	24	14	21	-10	3.2	269	-0.5	11.0	6.0	4.3	65	30	3
12216	15	36	22	36	-5	7.7	364	-1.0	14.0	14.0	5.8	59	30	-1
12236	12	20	10	22	-10	0.5	318	-0.5	5.1	5.0	4.7	53	25	1
12311	-10	40	23	32	-5	5.3	249		15.0	16.0	4.0	66		
12331	12	29	15	21	-10	5.8	402	-0.5	3.3	6.4	4.8	67	23	2
12312	10	38	22	29	-5	6.0	268		16.0	17.0	4.1	70		
12332	10	28	12	24	-10	6.4	386	-0.5	12.0	6.4	5.2	68	10	1
12313	12	37	22	29	-5	7.0	286		19.0	17.0	4.7	70		
12333	9	29	9	21	-10	3.7	187	-0.5	13.0	19.0	7.3	60	24	-1
12314	10	44	22	27	-5	6.3	173	-1.0	18.0	16.0	2.9	60		
12334	9	32	7	25	-10	8.6	336	-0.5	11.0	6.3	6.0	71	20	-1
12315	-10	38	21	32	-5	5.6	160	-1.0	19.0	13.0	4.0	56	24	-1
12335	9	29	9	30	-10	4.2	253	-0.5	13.0	6.8	4.4	69	22	-1
12316	10	34	18	41	-5	5.0	274	-1.0	15.0	18.0	6.2	74		
12336	11	28	7	34	-10	3.6	192	-0.5	11.0	16.0	6.7	55	19	-1

TABLE B-3. PLANT DATA

SAMPLE NUMBER	COLLECTION DATE	PLANT PART	NH4 UG/GM-N	TOTAL ORGN -N MG/GM-N	NO2+NO3 UG/GM-N	TOTAL P MG/GM	TOTAL S UG/GM	TOTAL COLI #/GM	FECAL COLI #/GM	AS UG/GM	B UG/GM	CD UG/GM	CA MG/GM	CO UG/GM
1111	08/10/76	LEAF	322	12.6	477	2.3	871	0	0	-1	36.3	-2	9.27	-5
1121	08/10/76	LEAF	202	14.7	678	2.1	902	0	0	-1	39.5	-2	9.35	-5
1131	08/10/76	LEAF	482	15.4	1590	2.5	759	0	0	-1	22.1	-2	8.66	-5
1211	08/10/76	LEAF	446	18.8	665	3.6	529	0	0	1	39.7	-2	7.22	-5
1221	08/10/76	LEAF	576	16.4	656	3.0	1006	0	0	2	25.9	-2	6.56	7
1231	08/10/76	LEAF	920	23.2	780	3.7	687	0	0	-1	18.4	-2	7.09	-5
1212	08/10/76	GRAIN	60	10.8	922	3.0	359	0	0	-1	7.5	-2	.09	-5
1222	08/10/76	GRAIN	47	10.3	838	3.4	375	0	0	1	3.9	-2	.06	-5
1232	08/10/76	GRAIN	46	9.1	585	4.3	357	0	0	-1	15.3	-2	.12	-5

Table B-3. Continued

SAMPLE NUMBER	CR UG/GM	CU UG/GM	PB UG/GM	MG MG/GM	MN UG/GM	HG UG/GM	NI UG/GM	K MG/GM	NA UG/GM	ZN UG/GM	SE UG/MG	ENDRIN NG/GM	LINDANE NG/GM
1111	7	12	-10	1.4	38	-3	-5	.5	78	44	0.5	-.025	0.07
1121	5	12	-10	1.3	47	-3	-5	.5	80	63	-0.5	-.025	1.13
1131	8		-10	0.9	61	-3	-5	.5	66	65	-0.5	-.025	0.02
1211	6	17	-10	0.9	96	-3	-5	.5	123	57	0.6	-.025	0.26
1221	7	23	-10	6.4	57	-3	-5	6	71	72	-0.5	-.025	1.68
1231	7	18	-10	6.9	77	-3	-5	.5	129	63	-0.5	-.025	0.22
1212	3	12	-10	0.6	-10	-3	-5	.5	74	30	-0.5	-.025	0.46
1222	7	12	-10	0.3	-10	-3	6	.5	54	22	-0.5	-.025	0.36
1232	2	8	-10	0.2	-10	-3	-5	.5	33	27	-0.5	-.025	0.53

Table B-3. Continued

SAMPLE NUMBER	METHOXYCHLOR NG/GM	TOXAPHENE NG/GM	2,4-D NG/GM	SILVEX NG/GM
1111	-.02	-.02	26.7	2.67
1121	-.02	-.02 -	0.12	24.0
1131	-.02	-.02 -	0.12	6.06
1211	-.02	-.02	3.74	0.66
1221	-.02	-.02	107	33.6
1231	-.02	-.02	10.9	5.02

APPENDIX C

NITROGEN RELATIONSHIPS IN THE ROSWELL, NEW MEXICO, LAND APPLICATION SYSTEM

The data for inorganic nitrogen and organic nitrogen for the soils are tabulated in Table C-1 and Table C-2. The unit KG/CM-HA is consistently used in the tabulation and following analysis. The first step in the analysis was to compute various means (see Table C-3) to facilitate observation of trends. The following trends were observed:

Observation 1: Organic nitrogen concentration at the test site was greater than the organic nitrogen at the control site for depths less than 10 cm. For depths greater than 10 cm, no difference was observed.

Observation 2: There was a consistent decrease of organic nitrogen with increased depth at the control and the test site.

Observation 3: Inorganic nitrogen concentration at the test site is greater than the inorganic nitrogen concentration at the control site for depths less than 30 cm. For depths greater than 30 cm, no difference is observed.

Observation 4: There was a seasonal decrease in inorganic nitrogen from June, 1976, to January, 1977.

An analysis using statistical and regression techniques was applied to the data to validate the accuracy of the observations made above. The analysis is summarized in the following narrative.

Observation 1: Organic nitrogen concentration at the test site was greater than the organic nitrogen at the control site for depths less than 10 cm. For depths greater than 10 cm, no difference was observed.

A statistical analysis of the data was performed to establish the validity of this observation. The approach was to hypothesize that the means for the test and control sites were equal and then test the hypothesis at the 5% significance level (95% confidence limit) by forming a random variable which has Student's t-distribution. The data used in the analysis are presented in Table C-4.

$\bar{x}_1$ = Sample mean organic nitrogen value for the soil at the test site at a specified time and for a specified depth range.

n_1 = Number of sample values used to compute $\bar{x}_1$.

s_1^2 = Sample variance.

$\bar{x}_2$ = Sample mean organic nitrogen value for the soil at the control site at a specified time and for a specified depth range.

n_2 = Number of sample values used to compute $\bar{x}_2$.

s_2^2 = Sample variance.

u_1 = Actual mean organic nitrogen value for the soil at the test site at a specified time and for a specified depth range.

TABLE C-1. INORGANIC AND ORGANIC NITROGEN DATA FOR THE CONTROL SITE (KG/CM-HA)

Sample Date	Sample Code	Depth (0-2 cm)		Depth (2-4 cm)		Depth (9-11 cm)		Depth (29-31 cm)		Depth (95-105 cm)		Depth (295-305 cm)	
		IN-N	TON-N	IN-N	TON-N	IN-N	TON-N	IN-N	TON-N	IN-N	TON-N	IN-N	TON-N
6/76	11111		237.1										
	11112				303								
	11113					9.9	165						
	11114							14.8	183				
	11211	19.5	191										
	11212												
	11213					15.7	248						
	11214								195				
	11311	5.2	215										
	11312			9.3	340								
	11313					13.3	226						
	11314							17.5	206				
	11115									13.8	119		
	11116											10.7	65
	11215									4.6	62		
	11216											9.5	36
	11315									2.4	216		
	11316											8.7	102
1/77	11131	3.1	432										
	11132			2.5	302								
	11133					4.2	237.5						
	11134							2.2	151				
	11231	4.4	541										
	11232			4.5	281								
	11233					3.6	129						
	11234							3.0	86				
	11331	2.8	302										
	11332			2.9	259								
	11333					3.4	151						
	11334							3.1	172				
	11135									3.8	63		
	11136											1.5	64
	11235									2.7	85		
	11236											3.2	64
	11335									3.4	107		
	11336											4.6	43

TABLE C-2. INORGANIC AND ORGANIC NITROGEN DATA FOR THE TEST SITE (KG/CM-HA)

Sample Date	Sample Code	Depth (0-2 cm)		Depth (2-4 cm)		Depth (9-11 cm)		Depth (29-31 cm)		Depth (95-105 cm)		Depth (295-305 cm)	
		IN-N	TON-N	IN-N	TON-N	IN-N	TON-N	IN-N	TON-N	IN-N	TON-N	IN-N	TON-N
6/76	12111		281.9										
	12112				280.8								
	12113					9.5	361.4						
	12114							18.7	155.5				
	12211		641.2										
	12212				475 1								
	12213					20.7	307.1						
	12214							13.3					
	12311		379.0										
	12312				410.6								
	12313					17.5	381.4						
	12314							24.7	195.2				
	12115									4.0	84.9		
	12116											7.4	36.4
	12215									9.9	34.7		
	12216											10.0	34.2
	12315									10.4	57.2		
	12316											9.9	78.7
1/77	12131	6.1	627.3										
	12132			13.1	301.8								
	12133					13.6	215.8						
	12134							5.2	128.2				
	12231	10.2	518.5										
	12232			13.4	432.5								
	12233					12.7	280.8						
	12234							6.0	214.3				
	12331	7.5	431.4										
	12332			12.2	365.3								
	12333					10.2	237.3						
	12334							4.9	236.6				
	12135									3.0	107.0		
	12136											2.4	42.5
	12235									3.5	63.7		
	12236											4.9	39.9
	12335									4.5	106.8		

TABLE C-3. MEANS FOR DATA IN TABLE C-1 AND TABLE C-2 (KG/CM-HA)

Sample Date and Location	Depth (0-2) cm		Depth (2-4) cm		Depth (9-11) cm		Depth (29-31) cm		Depth (95-105) cm		Depth (295-305) cm	
	IN	ORG	IN	ORG	IN	ORG	IN	ORG	IN	ORG	IN	ORG
6/76 Control	12.4	214	9.3	322	13.0	213	13.6	194	6.9	132	9.6	68
1/77 Control	3.4	425	3.3	281	3.7	173	2.8	136	3.3	85	3.1	57
6/76 Test		434		389	15.9	350	18.9	175	8.1	59	9.1	50
1/77 Test	7.9	525	12.9	366	12.2	245	5.3	193	3.7	93	3.7	41

TABLE C-4. SUMMARY OF ORGANIC NITROGEN DATA FOR THE SOILS AT THE TEST SITE AND CONTROL SITE (KG/CM-HA)

Sample Location	Date	Depth (cm) 0-2	2-4	9-11	29-31	95-105	295-305
Test	6/76	282	281	361	155	85	36
		641	475	307	195	35	34
		379	411	381		57	79
	1/77	627	302	215	128	107	42
		518	432	281	214	64	40
		431	365	237	237	107	
Control	6/76	237	303	165	182	119	65
		191	340	248	195	62	36
		215		226	206	216	102
	1/77	432	302	237	86	63	64
		541	281	157	172	85	64
		302	259	129		107	43
					151		

u_2 = Actual mean organic nitrogen value for the soil at the control site at a specified time and for a specified depth range.

Restatement of hypothesis:

H: $u_1 = u_2$ at the 5% significance level (versus $u_1 \neq u_2$).

In general, the assumptions underlying the analysis are additivity, linearity, normality, independence, and homogeneous variances.

The ratio $\frac{\bar{x}_1 - \bar{x}_2}{S_{\bar{x}_1 - \bar{x}_2}}$ has a Student's t-distribution with $n_1 + n_2 - 2$ degrees of freedom.

Where

$$S_{\bar{x}_1 - \bar{x}_2} = \sqrt{\frac{s^2}{n_1} + \frac{s^2}{n_2}}$$

$$s^2 = \frac{(n_1 - 1)\, s_1^2 + (n_2 - 1)\, s_2^2}{n_1 + n_2 - 2}$$

The procedure is to calculate

$$t = (\bar{x}_1 - \bar{x}_2)/S_{\bar{x}_1 - \bar{x}_2}$$

and to reject H: $u_1 = u_2$ if

$$t \leq -t_{(1 - \frac{a}{2})(n_1 + n_2 - 2)}$$

or

$$t \geq t_{(1 - \frac{a}{2})(n_1 + n_2 - 2)}$$

$\pm t_{(1 - \frac{a}{2})(n_1 + n_2 - 2)}$ represents a value for a random variable with a Student's distribution, with $n_1 + n_2 - 2$ degrees of freedom where $1 - \frac{a}{2} = P\left[t \leq t_{(1 - \frac{a}{2})(n_1 + n_2 - 2)}\right]$, the values are obtained from standard statistical tables.

For the analysis a 5% level of significance was chosen so that $a = 0.05$.

A. Sample data for 6/76, depths 0-10 cm from Table C-4:

$\bar{x}_1 = 391$ $n_1 = 9$ ${s_1}^2 = 11,348.5$

$\bar{x}_2 = 241$ $n_2 = 8$ ${s_2}^2 = 2,861$

Then

$s^2 = 7,387$

$S_{\bar{x}_1 - \bar{x}_2} = 41.8$

$t = 3.59$

Now

$$t_{(1 - \frac{a}{2})(n_1 + n_2 - 2)} = t_{(0.975)(15)} = 2.131$$

Thus

$$t = 3.59 > 2.131 = t_{(0.975)(15)}$$

The hypothesis H: $u_1 = u_2$ is thus rejected, and we accept $u_1 \neq u_2$ at the 5% significance level.

In summary, at the 5% level there is a significant difference in the mean values of organic nitrogen for the soils at the test site and control site in the depth range 0-10 cm during 6/76. The same analysis above establishes a 95% confidence interval for $u_1 - u_2$. This interval is as follows:

$$60.9 \text{ KG/CM-HA} \leq u_1 - u_2 \leq 239 \text{ KG/CM-HA}$$

To supplement the above analysis, it is of interest to establish 95% confidence interval estimates for u_1 and u_2, respectively. This is also accomplished with a t-test since the variable $(\bar{x}_i - u_i)\sqrt{N/S_i}$ has a Student's t-distribution. Using the data in Table C-4, the following 95% confidence intervals are obtained:

$$309.1 \text{ KG/CM-HA} \leq u_1 \leq 472.9 \text{ KG/CM-HA}$$

and

$$196.3 \text{ KG/CM-HA} \leq u_2 \leq 285.7 \text{ KG/CM-HA}$$

That is, we are 95% confident u_1 and u_2 lie in the above intervals.

B. Sample data for 1/77, depths 0-10 cm from Table C-4:

$\bar{x}_1 = 379$ $n_1 = 9$ ${s_1}^2 = 16,570$

$\bar{x}_2 = 293$ $n_2 = 9$ ${s_2}^2 = 16,553$

$s^2 = 16,562$

$S_{\bar{x}_1 - \bar{x}_2} = 60.7$

$t = 1.42$

$t_{(0.975)(16)} = 2.120$

Now $t = 1.42 \leq t_{(0.975)(16)} = 2.120$

Thus, we accept $H: u_1 = u_2$

In summary, at the 5% level of significance there is no significant difference between the mean value of organic nitrogen in the soil at the test site and the control site for the depth range 0-10 cm during 1/77.

The 95% confidence intervals for u_1 and u_2 are respectively (same procedure as in A):

280 KG/CM-HA $\leq u_1 \leq$ 478 KG/CM-HA

194 KG/CM-HA $\leq u_2 \leq$ 392 KG/CM-HA

C. All sample data (6/76 and 1/77), depth 0-10 cm:

$\bar{x}_1 = 385$	$n_1 = 18$	$s_1^2 = 13,996.4$
$\bar{x}_2 = 268$	$n_2 = 17$	$s_2^2 = 10,425$

$\bar{x}_1 - \bar{x}_2 = 117$

$s^2 = 12,265$

$S_{\bar{x}_1 - \bar{x}_2} = 37.5$

$t = 3.12$

$t = 3.12 > t_{(0.975)(34)} = 2.030$

Thus, we reject $H: u_1 = u_2$ and accept $H: u_1 \neq u_2$

In summary, at the 5% level of significance for the 0-10 cm depth (6/76 - 1/77), the mean values of organic nitrogen at the test site and the control site are not equal.

As in part A above, the 95% confidence interval for this difference is:

41 KG/CM-HA $\leq u_1 - u_2 \leq$ 193 KG/CM-HA

The 95% confidence intervals for u_1 and u_2, respectively are:

326 KG/CM-HA $\leq u_1 \leq$ 444 KG/CM-HA

$216 \text{ KG/CM-HA} \le u_2 \le 321 \text{ KG/CM-HA}$

D. All sample data (6/76 and 1/77), depths 29-305 cm:

$\bar{x}_1 = 100.9$ $n_1 = 16$ $s_1^2 = 4,258$

$\bar{x}_2 = 112.2$ $n_2 = 18$ $s_2^2 = 3,561$

$\bar{x}_2 - \bar{x}_1 = 11.3$

$s^2 = 3,888$

$S_{\bar{x}_1 - \bar{x}_2} = 21.4$

$t = 0.527$

$t_{(0.975 \times 32)} = 2.042$

$t < t_{(0.975)(32)}$

Thus, accept: $H: u_1 = u_2$

At the 5% level of significance, there is no difference between the organic nitrogen in the soil at the test and control sites at depths greater than 10 cm.

The 95% confidence intervals for u_1 and u_2, respectively, are:

$66.2 \text{ KG/CM-HA} \le u_1 \le 136 \text{ KG/CM-HA}$

$82.5 \text{ KG/CM-HA} \le u_2 \le 142 \text{ KG/CM-HA}$

In summary, it can be said with some confidence that there is a significant difference in the organic nitrogen in the soils at the test and control site (part A) in the 0-10 cm depth range coinciding with the time effluent is being applied to the test site (6/76). This difference is no longer apparent by January, 1977 (part B). The excess organic nitrogen evidently has been transformed to the inorganic forms in this period of time and taken up by the crop, leached, etc. Part C shows how one could reach the conclusion that there is an overall difference in the nitrogen values, but consideration of part A and B shows this conclusion is probably not valid.

Finally, from part D it can be said with some confidence that there is no difference in the organic nitrogen at the control and test sites for depths greater than 10 cm.

Observation 2: There was a consistent decrease of organic nitrogen with increased depth at the control and test site. Regression analysis was used to evaluate this observation.

A linear relationship is observed by plotting the data in Table C-3 on log-log paper as shown in Figure C-1. On the basis of this observation, a regression analysis was performed on the data using the following variables:

$x = \log_{10}D$

D = depth of sample (cm)

$y = \log_{10}C$

C = concentration of organic nitrogen at depth D (KG/CM-HA)

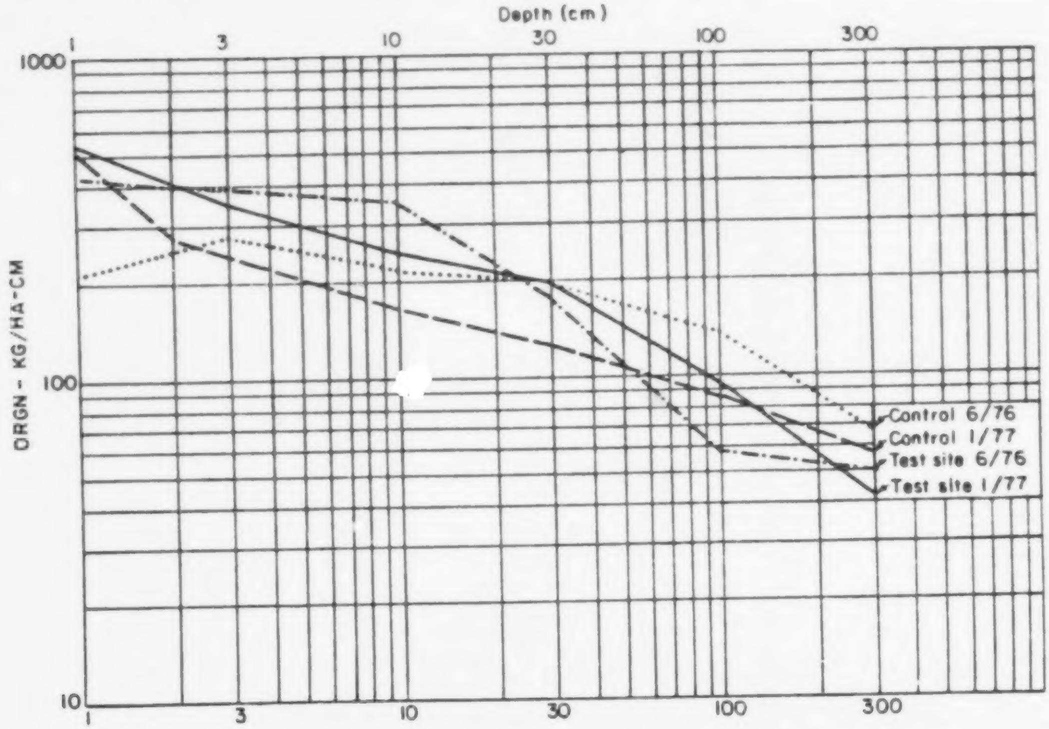

Figure C-1. Plot of data used in regression analysis.

The method of least squares was employed to obtain the best fit. Correlation coefficients (R) were computed in each case to evaluate the degree of correlation. The data and regression analysis results are presented in Table C-5. The following equations were obtained:

TABLE C-5. SUMMARY OF REGRESSION ANALYSIS

Sample Date and Location		Mean Sample Depth (cm)						Sample Statistical Parameter Values			Regression Analysis Results		
		1	3	10	30	100	300	Mean	s	s^2	Y intercept	M slope	R Corr. Coef.
	$\log_D$	0	0.477	1.0	1.477	2.0	2.477	1.24	0.93	0.72			
6/76 Control		2.33*	2.43	2.33	2.29	2.12	1.83	2.22	0.22	0.039	2.47	-0.199	-0.856
1/77 Control		2.70	2.45	2.22	2.11	1.93	1.76	2.19	0.34	0.098	2.65	-0.365	-0.993
6/76 Test		2.64	2.59	2.54	2.24	1.77	1.70	2.25	0.42	0.15	2.78	-0.428	-0.949
1/77 Test		2.72	2.56	2.39	2.29	1.97	1.61	2.26	0.41	0.14	2.78	-0.426	-0.976

*$\log_C = \log_{10}$ (concentration of organic nitrogen KG/CM-HA from Table C-3)

1. Control Site, 6/76:

   $y = -0.199\ x + 2.47$ $R = -0.856$

2. Control Site, 1/77:

   $y = -0.365\ x + 2.65$ $R = -0.9935$

3. Test Site, 6/76:

   $y = -0.428\ x + 2.78$ $R = -0.949$

4. Test Site, 1/77:

   $y = -0.426\ x + 2.78$ $R = -0.976$

In summary, the regression analysis indicates that a good correlation between concentration of organic nitrogen and depth exists at both the control site and the test site. This relationship persists for irrigation periods (6/76) as well as non-irrigation periods (1/77).

Observation 3: Inorganic nitrogen concentration at the test site is greater than the inorganic nitrogen concentration at the control site for depths less than 30 cm. For depths greater than 30 cm no difference is observed.

The objective of the analysis is to establish with some confidence statistically that a significant difference in the inorganic nitrogen for the soils at the test site compared to the control site exists for depths less than 30 cm. Also, for depths greater than 30 cm it will be established that no significant difference exists at the two sites. The approach will be identical to that used in the analysis for Observation 1. A 5% level of significance will be used for the analysis. The data used in the analysis is summarized in Table C-6.

$\bar{x}_1$ = Sample mean inorganic nitrogen value for the soil at the test site at a specified time and for a specified depth range.

n_1 = Number of sample values used to compute $\bar{x}_1$.

s_1^2 = Sample variance.

$\bar{x}_2$ = Sample mean inorganic nitrogen value for the soil at the control site at a specified time and for a specified depth range.

n_2 = Number of sample values used to compute $\bar{x}_2$.

TABLE C-6. SAMPLE DATA USED FOR INORGANIC NITROGEN ANALYSIS

Sample Date and Location	Depth (0-2) cm	Depth (2-4) cm	Depth (9-11) cm	Depth (29-31) cm	Depth (95-105) cm	Depth (295-305) cm
1/77 Test	6.1	13.1	13.6	5.2	3.0	2.4
	10.2	13.4	12.7		3.5	4.9
	7.5	12.2	10.2	4.9	4.5	
1/77 Control	3.1	2.5	4.2	3.0	3.8	1.5
	4.4	4.5	2.2	3.1	2.7	3.2
	2.8	2.9	3.6	3.4	3.4	4.6
6/76 Test			9.5	18.7	4.0	7.4
			20.7	13.3	9.9	10.0
			17.5	24.7	10.4	9.9
6/76 Control			9.9	14.8	13.8	10.7
			15.7	12.5	4.6	9.5
			13.3		2.4	8.7

s_2^2 = Sample variance.

u_1 = Actual mean inorganic nitrogen concentration for the soil at the test site at a specified time and for a specified depth range.

u_2 = Actual mean inorganic nitrogen concentration for the soil at the control site at a specified time and for a specified depth range.

Restatement of Hypothesis:

H: $u_1 = u_2$ at the 5% significance level (versus $u_1 \neq u_2$). The assumptions are the same as for Observation 1.

A. Sample data for time period 1/77, depths 0-31 cm:

$\bar{x}_1 = 9.598$ $n_1 = 12$ $s_1^2 = 11.024$

$\bar{x}_2 = 3.308$ $n_2 = 12$ $s_2^2 = 0.4985$

then

$s^2 = 5.761$

$S_{\bar{x}_1 - \bar{x}_2} = 0.9799$

$t = 6.42$

Now

$t_{(0.975)(22)} = 2.074$

Thus $t = 6.42 \geq 2.074 = t_{(0.975)(22)}$

The hypothesis H: $u_1 = u_2$ is rejected and $u_1 \neq u_2$ is accepted at the 5% level of significance. That is, at the 5% level we can be confident the means of the inorganic nitrogen for the soils at the control site and test site are not equal for the time period 1/77 and at depths less than 30 cm.

The same analysis above also establishes a 95% confidence interval for $u_1 - u_2$. This interval is as follows:

4.257 KG/CM-HA $\leq u_1 - u_2 \leq$ 8.322 KG/CM-HA

To supplement the above analysis, it is of interest to establish 95% of confidence interval estimates of u_1 and u_2, respectively. This is also accomplished with a t-test, since the variable $(\bar{x}_i - u_i)\sqrt{n/s}$ has a Student t-distribution.

Using the data, the following 95% confidence intervals are obtained:

$7.489 \text{ KG/CM-HA} \leq u_1 \leq 11.706 \text{ KG/CM-HA}$

$2.859 \text{ KG/CM-HA} \leq u_2 \leq 3.767 \text{ KG/CM-HA}$

That is, we are 95% confident u_1 and u_2 lie in the above intervals.

A. Sample data for 6/76, depth 9-30 cm: (Note - no data available at test site for depths 0-9 cm on 6/76.)

$\bar{x}_1 = 17.4$ $n_1 = 6$ $s_1^2 = 24.18$

$\bar{x}_2 = 13.2$ $n_2 = 5$ $s_2^2 = 4.04$

Then

$s^2 = 15.2$

$S_{\bar{x}_1 - \bar{x}_2} = 2.36$

$t = 1.78$

$t_{(0.975)(9)} = 2.26$

Now

$t = 1.78 \leq 2.26 = t_{(0.975)(9)}$

The hypothesis H: $u_1 = u_2$ is accepted at the 5% level of significance. That is, at the 5% level there is no significant difference in the mean values of inorganic nitrogen for the soils at the test site and control site in the depth range 9 to 30 cm during 6/76.

B. Sample data for 1/77, depths >30 cm:

$\bar{x}_1 = 3.67$ $n_1 = 5$ $s_1^2 = 0.84$

$\bar{x}_2 = 3.21$ $n_2 = 6$ $s_2^2 = 0.93$

$s^2 = 0.89$

$S_{\bar{x}_1 - \bar{x}_2} = 0.568$

$t = 0.809$

$t_{(0.975)(9)} = 2.26$

$t = 0.809 \leq 2.26 = t_{(0.975)(9)}$

Thus at the 5% level of significance we accept the hypothesis H: $u_1 = u_2$.

The 95% confidence limits for u_1 and u_2 are:

2.54 KG/CM-HA $\leq u_1 \leq$ 4.81 KG/CM-HA

2.20 KG/CM-HA $\leq u_2 \leq$ 4.22 KG/CM-HA

C. Sample data for 6/76, depths >30 cm:

$\bar{x}_1 = 8.62$	$n_1 = 6$	$s_1^2 = 5.08$
$\bar{x}_2 = 8.28$	$n_2 = 6$	$s_2^2 = 14.35$

$s^2 = 9.71$

$S_{\bar{x}_1 - \bar{x}_2} = 1.80$

$t = 0.19$

$t_{(0.975)(10)} = 2.228$

$t = 0.19 \leq 2.228 = t_{(0.975)(10)}$

Thus we accept, at the 5% level of significance, the hypothesis that $u_1 = u_2$.

The 95% confidence limits for u_1 and u_2 are:

6.26 KG/CM-HA $\leq u_1 \leq$ 10.98 KG/CM-HA

4.3 KG/CM-HA $\leq u_2 \leq$ 12.26 KG/CM-HA

To summarize, it can thus be stated with some confidence (5% level of significance) that there is a significant difference in the inorganic nitrogen for the soils at the test site and control site for depths less than 30 cm (part A) coinciding with the time somewhat after effluent application has ceased (1/77). This is in direct contrast to the organic nitrogen value results, which were observed (Observation 1) to have no significant difference in this period (1/77) at the two sites.

Also, there is no significant difference in the inorganic nitrogen values at the control site and the test site for depths less than 30 cm during the period effluent is being applied (6/76). Again, this is in contrast to the observation (Observation 1) that a significant difference in the organic nitrogen at the control site and the test site exists during this period (6/76).

The above can be explained by noting that the effluent is high in organic nitrogen and thus one would expect an excess to accumulate during the irrigation period at the control site. Then as irrigation ceases, nitrification and other transformations change the excess organic nitrogen into the inorganic forms. Some of the transformed nitrogen can be used by the plants, given off as gas through denitrification, etc. Further, if there is an excess of inorganic nitrogen produced and not utilized in these processes, then one would expect there to be a residual of inorganic nitrogen present at a time somewhat after irrigation ceases. The statistical analysis shows that indeed this is what occurs at the test site in Roswell, New Mexico.

In addition, it can be stated with some confidence that there is no significant difference in the inorganic nitrogen at the test site and the control site for any period of the year for depths greater than 30 cm.

Observation 4: There was a seasonal decrease in organic nitrogen from June, 1976, to January, 1977.

A statistical analysis identical to that used in Observation 1 and Observation 3 is utilized to test the above hypothesis. Table C-7 summarizes the data used in the analysis.

TABLE C-7. SUMMARY OF INORGANIC NITROGEN DATA USED IN ANALYSIS OF OBSERVATION 4 (KG/CM-HA)

Sample Date and Location	Relative Depth of Sample (cm)					
	0-30			30-305		
	$\bar{x}$	n	s^2	$\bar{x}$	n	s^2
6/76 Test	17.4	6	24.18	8.62	6	5.08
1/77 Test	9.6	12	11.024	3.67	5	0.84
6/76 Control	13.2	5	4.04	8.28	6	14.35
1/77 Control	3.3	12	0.4985	3.21	6	0.93

Let u_1 = actual mean of the inorganic nitrogen at the test (or control) site for 6/76 for a specified depth.

u_2 = actual mean of the inorganic nitrogen at the test (or control) site for 1/77 for a specified depth.

The hypothesis to test can thus be restated: H: $u_1 = u_2$ versus $u_1 \neq u_2$.

A. Sample data for the test site at depth 0-30 cm:

$\bar{x}_1 = 17.4$ (6/76) $\quad n_1 = 6 \quad s_1^2 = 24.18$

$\bar{x}_2 = 9.6$ (1/77) $\quad n_2 = 12 \quad s_2^2 = 11.024$

$s^2 = 15.13$

$S_{\bar{x}_1 - \bar{x}_2} = 1.94$

$t = 4.01$

$t_{(0.975)(16)} = 2.12$

Now $t = 4.01 \geq 2.12 = t_{(0.975)(16)}$

Thus, we reject the hypothesis H: $u_1 = u_2$ and accept $u_1 \neq u_2$. That is, at the 5% level there is a significant difference in the mean values of the inorganic nitrogen at the test site for the period 6/76 compared to 1/77 for the depth 0-30 cm.

The 95% confidence interval for $u_1 - u_2$ is:

37 KG/CM-HA $\leq u_1 - u_2 \leq$ 11.9 KG/CM-HA

Note that in previous observations, 95% confidence intervals for u_1 and u_2 have been computed.

B. Sample data for the test site at depth >30 cm:

$\bar{x}_1 = 8.62$ (6/76) $\quad n_1 = 6 \quad s_1^2 = 5.08$

$\bar{x}_2 = 3.67$ (1/77) $\quad n_2 = 5 \quad s_2^2 = 0.84$

$s^2 = 3.20$

$S_{\bar{x}_1 - \bar{x}_2} = 1.08$

$t = 4.57$

$t_{(0.975)(9)} = 2.262$

Now $t = 4.57 \geq 2.26 = t_{(0.975)(9)}$

Thus at the 5% level there is a significant difference in the mean values of the inorganic nitrogen at the test site for the period 6/76 versus 1/77 for depths greater than 30 cm.

The 95% confidence interval for $u_1 - u_2$ is:

2.51 KG/CM-HA $\leq u_1 - u_2 \leq$ 7.39 KG/CM-HA

C. Sample data for the control site at depths 0-30 cm:

$\bar{x}_1 = 13.2$ (6/76) $n_1 = 5$ $s_1^2 = 4.04$

$\bar{x}_2 = 3.3$ (1/77) $n_2 = 12$ $s_2^2 = 0.4985$

$s^2 = 1.44$

$S_{\bar{x}_1 - \bar{x}_2} = 0.639$

$t = 15.5$

$t_{(0.975)(15)} = 2.131$

Now $t = 15.5 \geq 2.13 = t_{(0.975)(15)}$

Thus at the 5% level there is a significant difference in the mean values of the inorganic nitrogen at the control site for the period 6/76 versus 1/77 for depths less than 30 cm.

The 95% confidence interval for $u_1 - u_2$ is:

8.5 KG/CM-HA $\leq u_1 - u_2 \leq$ 11.3 KG/CM-HA

D. Sample data for the control site at depths >30 cm:

$\bar{x}_1 = 8.28$ (6/76) $n_1 = 6$ $s_1^2 = 14.35$

$\bar{x}_2 = 3.21$ (1/77) $n_2 = 6$ $s_2^2 = 0.93$

$s^2 = 7.64$

$S_{\bar{x}_1 - \bar{x}_2} = 1.60$

$t = 3.18$

$t_{(0.975)(10)} = 2.23$

Now $t = 3.18 \geq 2.23 = t_{(0.975)(10)}$

Thus at the 5% level there is a significant difference in the mean values of the inorganic nitrogen at the control site for the period 6/76 versus 1/77 for depths greater than 30 cm.

The 95% confidence interval for $u_1 - u_2$ is:

$1.50 \text{ KG/CM-HA} \leq u_1 - u_2 \leq 8.64 \text{ KG/CM-HA}$

In summary, significant decrease in inorganic nitrogen occurs from 6/76 to 1/77 at both the control site and test sites. This is characteristic for depths less than 30 cm as well as depths greater than 30 cm. The decrease in inorganic nitrogen coincides with the decrease in crop uptake, soil nitrification, and irrigation.

REFERENCE FOR APPENDIX C

Ostle, B. 1969. Statistics in Research. Iowa State University Press, Ames, Iowa.

GLOSSARY

Adsorption: A process in which soluble substances are attracted to and held at the surface of soil particles.

Advanced wastewater treatment: Additional treatment designed to reduce concentrations of selected constituents present in wastewater after secondary treatment.

Alkali soil: A soil with a high degree of alkalinity (pH of 8.5 or higher) or with a high exchangeable sodium content (15 percent or more of the exchange capacity) or both.

Aquiclude: A geologic formation which is porous and capable of absorbing water but will not transmit it rapidly enough to supply a well or spring.

Aquifer: A geologic formation or strata that contains water and transmits it from one point to another in quantities sufficient to permit economic development.

Consumptive use: Synonymous with evapotranspiration.

Conventional wastewater treatment: Reduction of pollutant concentrations in wastewater by physical, chemical, or biological means.

Drainability: Ability of the soil system to accept and transmit water by infiltration and percolation.

Effective precipitation: Precipitation that enters the soil and is useful for plant growth.

Evapotranspiration: The unit amount of water lost from a given area by transpiration, building of plant tissue, and evaporation from the soil surface, snow, or intercepted precipitation in a specified period of time.

Fixation: A combination of physical and chemical mechanisms in the soil that act to retain wastewater constituents within the soil, including adsorption, chemical precipitation, and ion exchange.

Groundwater: The body of water that is retained in the saturated zone that tends to move by hydraulic gradient to lower levels.

Groundwater table: The free surface elevation of the groundwater; this level will rise and fall with additions or withdrawals.

Infiltration: The entrance of applied water into the soil through the soil-water interface.

Infiltration-percolation: An approach to land application in which large volumes of wastewater are applied to the land, infiltrate the surface, and percolate through the soil pores.

Irrigation: Application of water to the land to meet the growth needs of plants.

Land application: The discharge of wastewater onto the soil for treatment or reuse.

Loading rates: The average amount of liquid or solids applied to the land over a fixed time period, taking into account periodic resting.

Lysimeter: A device for measuring percolation and leaching losses from a column of soil; also a device for collecting soil water in the field.

Micronutrient: A chemical element necessary for plant growth in amounts below 1 mg/L.

Mineralization: The conversion of an element from an organic form to an inorganic form as a result of microbial decomposition.

Overland flow: Wastewater treatment by spray-runoff (also known as "grass filtration") in which wastewater is sprayed onto gently sloping, relatively impermeable soil that has been planted to vegetation. Biological oxidation occurs as the wastewater flows over the ground and contacts the biota in the vegetative litter.

Pathogenic organisms: Microorganisms that can transmit diseases.

Percolation: The movement of water through the soil pores once it has passed the soil-water interface.

Phytotoxic: Toxic to plants.

Primary effluent: Wastewater that has been treated by screening and sedimentation.

Refractory organics: Organic materials not removed in secondary treatment.

Ridge-and-furrow method: The surface application of water to the land through formed furrows; wastewater flows down the furrows, and plants may be grown on the ridge.

Saline soil: A nonalkali soil containing sufficient soluble salts to impair its productivity.

Secondary treatment: Treatment of wastewater by physical, chemical, or biological means such as trickling filters, activated sludge, or chemical precipitation and filtration.

Sewage farming: Originally involved the transporting of sewage to rural areas for land disposal. Later practice includes reusing the water for irrigation and fertilization of crops.

Soil texture: The relative proportions of the various soil separates--sand, silt, and clay.

Soil water: That water present in the soil pores in an unsaturated zone above the groundwater table.

Spraying: Application of water to the land by means of stationary or moving sprinklers.

Spray-runoff: See overland flow.

Tilth: The physical condition of a soil as related to its ease of cultivation.

Transpiration: The net quantity of water absorbed through plant roots and transpired plus that used directly in building plant tissue.

Viruses: Submicroscopic biological structures containing all the genetic information necessary for their own reproduction but dependent for reproduction upon living cells.